GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM 1ST JANUARY

1897

TO THE 1ST APRIL

1898

UNDER THE DIRECTION OF

C. L GRIESBACH, C.I.E., F.G.S., etc.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
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8, HASTINGS STREET.

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PART I.—HEAD-QUARTER NOTES.

Change of date of Annual Report.

The Government of India having sanctioned that the Annual Report on the work performed by the department should be issued for the financial year instead of, as hitherto, for the calendar year, it follows that this, the first of the new issue of Annual Reports, has to embrace the entire period since the 1st January 1897.

During the greater part of this period I was absent on furlough and Mr. R. D. Oldham officiated for me.

Removal of the offices.

The long impending removal of the offices of the department into the new building was carried out successfully during the hot season of 1897. The new building has been erected by the Bengal Government under an arrangement with the Trustees of the Indian Museum, and was destined to provide accommodation conjointly for the offices of the Geological Survey of India and the Indian Museum.

Although the accommodation in this new building is superior to that formerly held in the Museum building, yet there are weighty objections to it. On a former occasion[1] I have had an opportunity to point out the advisability of removing the head-quarters of the department to a hill-station

[1] Memorandum of the 29th April 1895.

and the reasons adduced in favour of such a step remain as much in force now as ever. I still entertain the hope that this will be possible at an early date and as soon as the financial position improves.

MUSEUM AND LABORATORY. *Mr. H. H. Hayden, Curator, and Mr. T. R. Blyth, Museum Assistant.*

During January and February 1897 the office and laboratory were transferred into the new building, and during that period much of the work in the latter and laboratory had necessarily to stand over. After the move was completed, Mr. Hayden, assisted by Mr. Blyth, began the re-arrangement of the sedimentary rocks. This was almost completed, so far as the Indian series is concerned, when Mr. Hayden was sent into the field. The specimens have been arranged as far as possible in chronological order, those from each area being grouped together under their respective systems. The foreign series has been separated from the Indian, and it was intended to arrange them separately in the wall cases on the north side of the rock gallery.

The collection of economic specimens has been very largely increased during the past year, chiefly by the addition of corundum from various localities in the Madras Presidency. It will consequently be necessary to re-arrange, to a certain extent, portions of the economic collection in order to find more space for this mineral. The labelling of the economic specimens has been steadily progressing—fifty-two cases have now been completed, leaving 32 still to be done.

Minerals.—Among the more important additions to the collection of Indian minerals are—

Columbite.—A fine specimen (s. g. 6·19) was presented to the museum by Mr. A. Gow Smith .It was obtained from the Koderma Government forest, Házáribágh, which is a new locality for this mineral.

Altaite.—A specimen of auriferous quartz containing numerous grains and specks of altaite (Pb. Te) was presented by Mr. C. P. Wright, Wuntho, Burma.

Aluminite.—Although this mineral had been in our collection for some time, it was not known to be aluminite, having been labelled "beauxite" by its original collector. An analysis gave the formula $Al_2 O_3$, SO_3, $9H_2 O$. The specimen analysed came from Chitteedand in the Salt Range.

This is the first time that either altaite or aluminite have been recorded as occurring in India.

The following is a list of donations made to the Museum during the past year.

Donation.	*Presented by—*
Two tusks, teeth and part of skull of *Elephas Clifti*: from the Gabhir ravine, Tallaganj Tahsil, Jhelum district.	J. Wilson, Esq., Deputy Commissioner, Rawalpindi District.
Three species of a *meteorite* that fell at Nawapali, Sambalpur district, at 6 P.M. on June 6th, 1890.	L. S. Carey, Esq., I.C.S., Commissioner of Settlements and Agriculture, C. P.
Specimen of *Sperrylite* from Vermillion mine, Sudbury, Ontario.	Dr. T. L. Walker, Geological Survey of India.
Specimens of *muscovite*: *muscovite* w. *garnet* and *tourmaline*; *pseudomorphic quartz*, in muscovite: a large crystal of *garnet*: 3 specimens of *columbite* from the Koderma Government forest, Hazáribágh.	A. Gow Smith, Esq.
Specimens of *tourmaline*, *quartz* etc., from hillocks near Ranchi, Chota Nagpur.	Sarat Chundra Ghosh, Chinsurah.
Specimens of *muscovite*, with *tourmaline* and *ferruginous inclusions*: from the Koderma Government forest, Hazáribágh.	A. Gow Smith, Esq.
Fragment of the *Yenshigahara meteorite*	Trustees of the British Museum through L. Fletcher, Esq.
Nickeliferous pyrite, from Sudbury, Ontario . .	Dr. T. L. Walker.
Miocene fossils, from the Upper Chindwin, Burma	A. Smythies, Esq., Conservator of Forests, Mandalay, Burma.
A collection of rocks from DeBeers Diamond mines, Kimberley, South Africa.	C. L. Griesbach, Esq., C. I. E.

COLLECTION OF TYPE FOSSILS.

After my return to duty on the 24th November 1897, I decided to have the large collection of described type fossils re-arranged into specially constructed cases. Dr. Fritz Nœtling and Mr. Hayden, who, had returned from the Tirah Field Force beginning of January, were the officers who have very ably carried out this important work, in which they were assisted by Mr. Blyth, the Museum Assistant. The work was most tedious, and required the utmost care, but the principal part of it has now been finally accomplished. Each specimen has been checked and compared with the figure given of it in our publications, and will be registered in a special catalogue, so that it can always be again referred to without any difficulty. It has now been ascertained that a number of the older specimens have disappeared, lost probably during a former removal into galleries of the Indian Museum. But the lost specimens are not very numerous and almost entirely confined to the cretaceous series of Southern India. Such loss will now be impossible, short of theft, each specimen having been marked with proper numbers painted on and corresponding to the catalogue.

Assays made in the Laboratory.

Substance.	For whom.	Result.
One specimen of Lignite, containing plant remains and specks of resin, found at the bottom of a well, 201 feet from surface, Pallana, about 12 miles from Bickanir, Rajputana.	Lieut.-Col. H. A. Vincent, Political Agent, Bickanir.	*Quantity received*, 7 lb. Moisture . . . . 12·50 Volatile matter . . . . 41·40 Fixed carbon . . . . 37·50 Ash . . . . 8·60 100·00 Does not cake. Ash—light grey.
Three specimens of minerals, for determination.	Geo. Watt, Reporter on Economic Products to the Govt. of India.	*No. 1.—From Kabul.* Travertine. *No. 2.—From Sakesar and Kalabagh, Punjab.* Massive gypsum. *No. 3.—From Kabul.* Bowenite (Pseudo Jade).
One specimen of Psilomelane, from Gosalpur, Jabalpur district, for phosphorus.	C. W. McMinn, Jabalpur.	Contains ·589 per cent. phosphoric anhydride (P_2O_5).
A white mineral, found underneath the coal strata, Chitteedand, Salt Range, supposed to be Beauxite.	Museum, Geological Survey of India, Calcutta.	S. G. 1·707 SO_3 . . . . . . 23·63 H_2O . . . . . 46·44 AL_2O_3 . . . . . 30·08 CaO . . . . . trace. Fe_2O_3 . . . . . „ ZnO . . . . . „ 100·15 = Aluminite.
Three specimens from Bishahir, supposed to be Saphire.	R. G. Thomson, C. S., Deputy Commissioner, Simla district.	= Amethyst.

Assays made in the Laboratory—contd.

Substance.	For whom.	Result.						
			"No. 4 pit, Far north district, 3 seam."	"No. 4 pit, rise Bar district, 3 seam."	"No. 5 pit, 18 rise, 3 seam."	"No. 5 pit, S. A. R., 2 seam."	"No. 5 pit, main dip, 3 seam."	"Main dip, 2 seam."
Six specimens of coal from the Warora Colliery.	C. O. Leefe, Assistant Secretary to Chief Commissioner, Public Works Department, Central Province, Nagpur.	*Quantity received.*	10lbs.	10lbs.	10lbs.	10lbs.	10lbs.	10lbs.
		Moisture	8·40	9·78	6·52	7·40	6·38	10·40
		Volatile matter.	29·00	29·62	27·10	20·48	19·64	30·42
		Fixed carbon.	42·74	43·72	40·08	36·44	31·62	41·12
		Ash	19·86	16·88	26·30	35·68	42·36	18·06
			100·00	100·00	100·00	100·00	100·00	100·00
		Does not cake.						
			Ash—pale reddish grey.	Ash—reddish grey.	Ash—reddish grey.	Ash—light grey.	Ash—light grey.	Ash—light grey.
One specimen of Galena, from Arki, Baghal State Simla Hills.	R. G. Thomson, C.S., Deputy Commissioner, Simla District.	*Quantity received 2½lbs.* Yielded on assay, 75·17 per cent. lead (Pb); and 21 oz. 1 dwt. 9 grs. silver to the ton of lead.						

ssays made he Laboratory—con

Substance.	For whom.	Result.				
			I.	II.	III.	IV.
		Quantity received.	5¼ oz.	7 oz.	5⅜ oz.	4⅜ oz.
Four specimens of coal from Assam.	F. H. Smith, Geological Survey of India.	Moisture .	5·36	3·88	3·14	7·10
		Volatile matter	49·96	57·52	29·00	37·48
		Fixed carbon.	25·32	25·40	15·24	40·38
		Ash . .	19·36	13·20	52·62	15·04
			100·00	100·00	100·00	100·00
			Sinters slightly. Ash—light buff.	Sinters slightly. Ash—light buff.	Does not cake. Ash—light buff.	Does not cake. Ash—dark reddish brown.
One specimen of rock from the Jamuna river, Banda District, for identification.	S. M. Yusuffoozzaman, Banda City, Indian Midland Railway.	Concretionary hæmatite; lateritic.				
Two specimens of coal, from Assam.	F. H. Smith, A.R.C.S., Deputy Superintendent, Geological Survey of India.				A.	B.
		Quantity received.			10¾ oz.	4 oz.
		Moisture			10·74	9·40
		Volatile matter			31·12	34·42
		Fixed carbon			25·90	26·32
		Ash			32·24	29·86
					100·00	100·00
					Does not cake.	
					Ash—white.	Ash—pale white.

Assays made in the Laboratory—contd.

Substance.	For whom.	Result.
One specimen of lignite with specks of resin, from Pallana, 12 miles from Bikanir, Rajputana.	Tom. D. La Touche, B. A., Superintendent, Geological Survey of India.	*Quantity received,* 45lbs. Moisture . . . . 8·20 Volatile matter . . . . . . 42·72 Fixed carbon . . . . 39·48 Ash . . . . 9·60 100·00 Sinters slightly, but does not cake. Ash—light brown. Calorific power in heat units (C), 7,293. Evaporative power, 13·58.
Sixty specimens of quartz-barytes rock, from Tirupatur Taluk, Salem District, Madras, for an analysis of the Barytes; determination of the proportion of barytes and quartz; and an assay for gold.	C. S. Middlemiss, B.A., T. H. Holland, A.R.C.S., F.G.S., Supdts., Geological Survey of India.	Results to be published in Records, Vol. XXX, part 4, in a paper by C. S. Middlemiss and T. H. Holland.
Fragments of a rock for determination.	Col. H. A. Sawyer, I.S.C., 45th B.I., Malakand.	The fragments consist of quartz, felspar and muscovite, apparently derived from the disintegration of granite.
A specimen of iron pyrites from the Malakand, to know what it is embedded in.	Surgeon-Captain, D. St. J. D. Grant, M. B., Chemical Examiner to Government, Medical College, Lahore.	The matrix is limestone.
A specimen of "metal something like lead or plumbago", from Belbathan, for determination.	R. Carstairs, I.C.S., Deputy Commissioner of the Sonthal Parganas, Dumka.	Galena. A specimen from the same locality, received in 1889, yielded on assay 77·29 per cent. of lead; and 13 oz. 17 dwts. 16 grs. of silver to the ton of lead.
A heavy metallic looking specimen from the Koderma Government Forest, Hazaribagh District, supposed to be iron.	A. Gow-Smith, Hastings House, Alipore.	Columbite; S. G. 6·19.
Two specimens of minerals, washed from soil, for determination.	J. Walter Leather, Agricultural Chemist to the Government of India, Debra Dun.	Both specimens, impure lemonite.

Assays made in the Laboratory—contd.

Substance.	For whom.	Result.
Pebbles of schist containing quartz from the Wa States, Upper Burma, for gold.	The Chief Secretary to the Government of Burma, Rangoon.	*Quantity received, 14 lbs.* Yielded on assay, 10·5 grains of gold to the ton.
"Substances that came out of the earth along with sand and water, on the north and east banks of the Brahmaputra, during the earthquake of 12th June 1897."	Hiranmoy Mukerjee, Muktagacha, Mymensing District.	Lignite, resin and micaceous sand.
"A piece of black substance and some resinous-looking stuff that came out from an earthquake fissure at Mankar Char on the east bank of the Brahmaputra."	The District Engineer, Rungpur.	One of the specimens is a form of lignite, the other a resin. The lignite was probably derived from the disintegration of beds containing that mineral and similar to those seen in the Garo Hills.
Six specimens of minerals from the vicinity of North-West Baluchistan.	T. Webb-Ware, Political Assistant, Chagai-Quetta.	1. Sulphur. 2. Sulphate of alumina. 3. Galena. 4. Micaceous iron. 5. Red ochre. 6. Yellow ochre.
A specimen of granitite from Urumalia quarry, ½ mile south-west of Karasamir, South Arcot District, Madras.	T. H. Holland, A.R.C.S., F.G.S., Offg. Superintendent, Geological Survey of India.	No. 9·785. Specific gravity 2·818. SiO . . . . 58·30 Al_2O_3 . . . . 20·76 Fe_2O_3 . . . . 2·59 FeO . . . . 3·84 CaO . . . . 8·38 MgO . . . . 2·62 Na_2O . . . . 4·21 K_2O . . . . ·71 Loss on ignition . . . . . . ·20 ——— 101·61

Assays made in the Laboratory—contd.

Substance.	For whom.	Result.
A specimen of hyperathene hornblende granite from Perumbakam, Madras.	T. H. Holland, A.R.C.S., F.G.S., Offg. Superintendent, Geological Survey of India.	No. 9·791. Specific gravity 2·787. SiO_2 . . . . 61·40 Al_2O_3 . . . . 19·38 Fe_2O_3 . . . . ·58 FeO . . . . 5·27 CaO . . . . 6·56 MgO . . . . 3·24 Na_2O . . . . 2·78 K_2O . . . . ·44 Loss on ignition . . . . . . ·15 99·08
Alkaline salt from Yenangyat, Upper Burma, occurring as an incrustation.	G. E. Grimes, A. R. S. M.B.S.C., *etc.*, Assistant Superintendent, Geological Survey of India.	Soluble in hot water. Na_2O . . . . 34·89 K_2O . . . . ·24 CaO . . . . 1·25 MgO . . . . 1·80 SO_3 . . . . 48·09 Cl . . . . ·32 Loss on ignition . . . . . . 4·65 Insoluble in hot water . . . . . 10·00 101·24 Less oxgyen equivalent . . . . . ·08 101·16 Distinctly alkaline with litmus.
A specimen of elæolite from elæolite syenite, from Sivamalai, Coimbatore district, Madras.	T. H. Holland, A.R.C.S., F.G.S., Offg. Superintendent, Geological Survey of India.	No. 11·464. Specific gravity 2·62. SiO_2 . . . . 43·35 Al_2O_3 . . . . 34·32 Fe_2O_3 . . . . 1·02 CaO . . . . ·82 K_2O . . . . 5·52 Na_2O . . . . 14·62 Loss on ignition . . . . . . ·75 100·40
Two pieces of stone found while sinking a well in Jugdispur Tatarpur, Chupra, Sarun district, for determination.	E. P. Chapman, C.S., Officiating Magistrate of Sarun.	Calcite.
A piece of igneous rock from a boring 270 feet deep in Kabwet, Upper Burma.	The Agent and Manager, Burma Coal Co., Ld., Kabwet, Upper Burma.	Dolerite.

Assays made in the Laboratory—concld.

Substance.	For whom.	Result.
Nineteen specimens of rocks and minerals, from the Banda district, for determination.	R. M. Thompson, Public Works Department, Banda.	(1) Granitoid gneiss. (2) Gneiss. (3) „ (4) Pegmatite. (5) „ (6) „ (7) Probably decomposed syenite. (8) „ „ „ (9) Quartz. (10) „ (11) „ (12) „ (13) Amethyst. (14) Chalcedony. (15) „ (16) Breccia of flint fragments. (17) Siliceous sinter. (18) Hornblende gneiss. (19) Flint.
A specimen of coal taken from the diamond drill boring in the vicinity of the Eeb bridge on the B. N. R., Rampur coal-field.	The Junior Consulting Engineer to the Government of India for Railways, Nagpur.	A piece of the core taken from between the 429th and 430th foot, weight 12 oz. Moisture . . . . 5·30 Volatile matter . . . . . . 27·74 Fixed carbon . . . . . . 49·78 Ash . . . . 17·18 100·00 Sinters slightly, but does not cake. Ash—dark reddish brown.
Sand found in a nala near Chumbal River.	Col. D. G. Pitcher, I.S.C., Director of Land Records, Gwalior State.	Garnet sand.
Mineral found in Government land in the Darjiling district supposed to contain copper.	Mr. Finucane, C.S.I., Secretary to Government of Bengal.	Mixture of iron and copper pyrites.

Dr. Nœtling was absent on furlough till June 1897; after his return to duty he set to work at the determination and description of the large collection of Burman fossils in the Museum, in part collected by himself and in part by former workers in Burma, as for instance Messrs. Theobald, Blanford, Fedden, Dr. Oldham and later by Mr. Grimes. After weeding out useless and doubtful specimens, a fine collection of tertiary fossils remained, of which part, including the Antozoa, Echinodermata and Pelecypoda, has been described and is awaiting publication.

Palæontological work. Dr. Fritz Nœtling.

The results of the examination of the Pelecypoda are highly interesting and unexpected. It has hitherto been laid down as an axiom that the fauna living at present in the Indian ocean is closely related to the tertiary fauna of Europe. The tertiary Pelecypoda of Burma have, however, proved the absolute fallacy of this theory. For the majority of the species examined are either identical with species now inhabiting the Indian ocean, or are so closely related to living species that it seems impossible to avoid the conclusion that the latter are the direct descendants of the former. On the other hand, not a single species from Burma could be identified with any one from the tertiary system of Europe. There are a certain number of species which are identical with species which occur in the miocene of Java and Sumatra, and a smaller number still which are identical with species from the tertiary of Sind, but no relationship with the tertiary fauna of Europe could be discovered.

Two important facts are therefore almost proved by the examination of the tertiary Pelecypoda of Burma, *viz.*, (1) the fauna of the Indian Ocean is an old one, (2) no connection existed between the fauna of the upper tertiary, Indian ocean, and the upper tertiary, European ocean.

With regard to the first part there remains little doubt that the composition and facies of the fauna which lived during the upper tertiary period in Burma was exactly the same as the one now inhabiting the Indian ocean. The present fauna exhibits therefore not a modern type, but more properly speaking an older tertiary type. Further, if the present fauna of the Indian ocean bears the strongest relationship to the tertiary fauna of Burma, while the latter bears no relationship to the tertiary fauna of Europe, it is impossible that the living fauna of the Indian ocean can exhibit any relationship to the tertiary fauna of Europe. It is therefore not only very probable, but almost certain, that no connection existed between the Indian ocean of the upper tertiary period, and the European ocean of the same time. The fauna of the Indian ocean developed independently of that of Europe since the upper tertiary period, but it is most remarkable, that while the terrestric fauna which lived at the same time, and somewhat later on the Indian continent, underwent tremendous changes; the marine fauna did not change its habitus in the least, in fact, it might almost be said that hardly the species changed their aspect.

Under the above circumstances the question of the age to which the fauna described, belongs, becomes somewhat uncertain. There is no question about its belonging to the upper tertiary period, but whether it represents the miocene of pliocene period seems somewhat doubtful. Without entering into a lengthy discussion on the original definition of the terms miocene and pliocene the question could not be settled, but it appears very possible that the marine fauna of the upper tertiary of Burma represents the pliocene and very probably also the lower pliocene period. This would in some way explain the seemingly strange fact, that it has so few species in common with the tertiary beds of Sind, if we assume that the latter are of older age.

These views will of course be further dealt with when the whole of the fauna has been described, but, as already stated, the present examination has opened a road which leads towards new and unexpected results, in fact it tends to change the view hitherto held on the origin of the fauna of the Indian ocean. As an outcome of the specific examination of the tertiary fauna of Burma, two papers dealing with the morphology of the shells of the Pelecypoda have been submitted for publication, as the questions therein dealt with could not conveniently be included in a systematic description of the species.

Drawing office.

Mr. H. B. Wade Garrick, the Artist of the Department, reports that forty-seven lithographic plates have been prepared and 21,810 prints have been pulled off in the lithographic press of the Geological Survey of India, also 27 designs have been drawn on wood ready for the engraver.

In the map branch, a large number of geological boundaries have been transferred from field sheets and old M. S. maps, and compiled on to fair sheets to be kept for record in the office, and some maps printed by the Survey of India have also been coloured by our colourists.

Work of a miscellaneous nature has also been done, such as lithographed labels required for the laboratory, etc.; plates not intended for publication; pen drawings made for reproduction by photography, and lithographic practice work during spare time, etc. Finally, in connection with the Earthquake Report, a pen diagram has been made showing the river levels of the Ganges and Brahmaputra at Goalundo and Gauhati respectively during the years 1895, 1896 and 1897. This has been drawn to scale from the figures in the Irrigation Report of the Public Works Department, Bengal.

Library.

The additions to the Library during the year under review amount to 3,143 volumes and parts of volumes, of which 2,266 were acquired by presentation, and 877 by purchase.

Publications.

The Manual of the Geology of India.

The third part of the first edition of the Manual of Geology of India, which was prepared by the late Dr. V. Ball in 1881, has for several years been out of print. The preparation of a new edition on the same plan as the original

one would involve a greater interruption of the regular work of the survey than can at present be contemplated, and it is doubtful whether the result would be commensurate with the expenditure of time involved. Many minerals are of little economic interest at present, and the additions to our knowledge since the publication of Dr. Ball's volume are small, yet to bring these up to date would involve almost as much work, in many cases, as the revision of these parts dealing with minerals, such as mica, which have risen to an importance unthought of and regarding which our knowledge has been revolutionised rather than advanced.

Under these circumstances, and in view of the frequent applications for general information regarding specific minerals, a scheme of re-issue of this part of the manual by instalments has been sanctioned by Government. Each instalment will deal with a single mineral, or group of closely allied minerals, and in the first instance these will be selected with regard to which there has been the greatest change in the state of our knowledge since 1881. In this way, it is hoped that gradually, and without interrupting the regular work of the survey, it may be possible to re-issue the Manual of the Economic Geology of India, or at any rate such parts as are of sufficient interest to justify this course.

As a commencement, corundum and its gem forms ruby and sapphire was selected, and a handbook has been prepared by Mr. Holland treating on these minerals and giving a full account of all that is known at the present day regarding their occurrence in India This has been passed for press and will be issued forthwith.

Memoirs and Palæontologia Indica.

With the volume XXX of the "Records," this publication has ceased to exist as a separate serial of the Department, it having been found inconvenient to bring out reports at regular stated periods. In future all papers which were formerly brought out in the "Records" will be published in the "Memoirs" and "parts" of the latter, as matter for publication accumulates, will be issued at irregular intervals and grouped into volumes as heretofore.

The following "Memoirs" have been published since the 1st January 1897:—

Vol. XXVII, part 2,—The occurrence of Petroleum in Burma and its technical explo tation, by Dr. F. Nœtling.

The "Palæontologia Indica," which is at present arranged into so-called series, will in future be published in parts, and these be grouped into consecutive volumes of convenient size, containing palæontological reports, each complete in itself and as they are sent in, thus obviating the necessity of publishing descriptions of small collections in the "Memoirs," as often had to be done on former occasions when such papers could not be included in any one of the "series."

Such of the "series" which are not yet complete, as for instance the "Himalayan fossils," series XV, will of course be brought to a conclusion.

The following parts of the "Palæontologia Indica" have been issued since 1st January 1897 :—

Series XV, Vol. I, parts 3 and 4,
Vol. II, part I,

both of the Himalayan Fossils.

Series XVI, Vol. I, parts 2 and 3,

of the Baluchistan Fossils.

Geological maps.

A large number of geological maps on various scales and of different districts have been published in the Memoirs and Records of the Department, but as no general index of these has been prepared, it was impossible for strangers to know whether a geological map of any district in which they were interested was procurable or not. The number of applications for geological maps received shows that this was a real want, and two index maps have been prepared during the recess of 1897 under the superintendence of Dr. Walker, which show respectively the areas which are published on scales of four miles or less to the inch, and on the smaller scales of more than four miles to the inch; the area included in each map, and the volume and part with which it was published.

Personnel. The Director on furlough.

I rejoined and took over my office from Mr. Oldham on the 24th November of last year. I utilized the first nine months of my furlough to proceed to South Africa, in order to study the gold-bearing rocks of that part of the world, but chiefly those of the Transvaal, and also the conditions of the mining laws and industry of that country. Although this enquiry was of a private nature and carried out during absence on furlough, I refer to it here on account of its bearing to Indian conditions. I intend compiling a special report on the subject of the enquiry at a subsequent date.

Besides myself, the following officers were on leave during the period under report and rejoined on the dates mentioned below:—

Mr. Bose . . .	rejoined	15th May 1897.
Mr. Datta . . .	do.	17th March 1898.
Dr. Noetling . . .	do.	26th June 1897.

Sub-Assistant Hira Lal is on leave from the 6th September 1897.

Mr. William Anderson resigned his appointment as Mining Specialist on the 15th October 1896.

Dr. Thomas Leonard Walker joined the Department as Assistant Superintendent on the 8th May 1897.

Part II.—Field parties.

Distribution of the officers.

During the period under report the distribution of the staff of the Department was as follows :—

Mr. R. D. Oldham . . Officiating Director up to 24th November 1897; then on field work in Assam.

Mr. LaTouche . .	Western Rajputana; 1896 to 1897 head-quarters and Assam, Western Rajputana 1897 to 1898.
" C. S. Middlemiss . .	Madras; Salem and Coimbatore districts.
" Bose	Returned from furlough on the 15th May 1897; head-quarters and Eastern Bengal; cold weather season in the Central Provinces.
" Holland . . .	Madras; Salem district and Coorg.
" Datta . . .	Returned to duty on the 17th March of this year; head-quarters.
" Smith . . .	Assam and Central Provinces.
" Hayden . . .	Headquarters, Assam and the North-Western Frontier.
" Vredenburg . . .	South Rewa, Assam and Bhopal.
" Grimes . . .	Burma and Assam.
" Walker . . .	Joined the Department on first appointment on the 8th May 1897, and is attached to Mr. Holland in Coorg.
Lala Hira Lal . . .	Chota Nagpore head-quarters; and furlough from 1897.
" Kishen Singh . .	Bombay Presidency.

Field parties. The officers of the Department were grouped into the following parties during the period under report:—

Earthquake inquiry . . .	Mr. Oldham.
	" LaTouche.
	" Bose.
	" Smith.
	" Hayden.
	" Vredenburg.
	" Grimes.
Madras Presidency—	
Salem and Coimbatore districts .	Mr. Middlemiss.
	" Holland.
Coorg	" Holland.
	" Walker.
Bombay Presidency . . .	Lala Kishen Singh.
Rajputana Agency . . .	Mr. LaTouche.
Central India Agency . .	" Vredenburg.
Central Provinces . . .	" Bose.
	" Smith.
Assam	" Smith.

Burma . . . . Mr. Grimes.
North-West Frontier . . „ Hayden.

1. Earthquake inquiry.

THE EARTHQUAKE OF THE 12TH JUNE 1897.

A great event which affected the Department, may be referred to as the "great earthquake" of the 12th June 1897. As it turns out now, it forms one of the largest, perhaps the most extensive phenomenon of the kind known to mankind, at least as regards the great land-area over which it was felt. Government decided that a most searching inquiry, followed by a full report, should be instituted, and with that end in view all officers of the Department who were then available, were deputed to various parts of Assam and Bengal to observe and investigate the effects of the earthquake; Messrs. LaTouche, Bose, Smith. Hayden, Vredenburg and Grimes were engaged on that work, and in addition Mr. Oldham made two short trips into the disturbed country in August and October last year, and during the last field season he was engaged in traversing parts of the Garo and Khasia Hills, where the centre of the disturbance was, in order to study certain effects of it in greater detail, which may help in forming an explanation of the probable causes of the earthquake. He has been charged with the working out of all the reports and studies into a fully illustrated description of the event, which will be published in the memoirs of the Department.

At the same time orders were issued by Government to the local authorities to report fully on the effects of the earthquake. All the telegraph offices throughout India were instructed to report the time at which it was felt, and similar information was called for from all the station-masters on the line of railways within the area likely to be affected. Circulars have also been widely distributed and communicated to the press, which has readily assisted in the endeavour to collect information.

Mr. Oldham has sent in several very interesting notes during the progress of his inquiry, together with a short paper which is given here.

Mr. R. D. Oldham on the earthquake.

"At first there was a natural tendency to associate the earthquake with the great flexure which skirts the southern edge of the Assam range. This was believed to be a region of tectonic movement, while the plateau to the north was regarded as a more stable region.

The existence of the depression of the Brahmaputra valley shows that this region has, in geological recent times, been subject to extensive changes of level, but the tendency to regard its southern edge as the principal zone of movement, in view of the geological structure and orographical relief of the region, probably represents the truth. From this it was a natural step to conclude that what had been a zone of greatest movement in recent times, was also the zone along which the forces of the earthquake must be looked

for. At a very early stage in the investigation of the earthquake this conclusion became questionable. It was found that if the centre was placed anywhere along the southern edge of the hill, there was a most unaccountably rapid falling off in intensity of the disturbance in a southerly as opposed to a northerly direction. Further, as soon as it was possible to arrange for some sort of a record of the aftershocks, it was found that at stations along the northern edge of the hills they were extremely abundant, so much so that in preparing a list of aftershocks, I found it necessary to exclude the returns from Goalpara and all places south of the Brahmaputra in that district, as well as those from Shillong and Tura. All this region was subject to a number of small shocks which did not spread beyond it and which seemed to be for the most part very local in their extent even within the region lying between the three stations mentioned.

From these facts, the supposition, that the centre of the earthquake lay along the southern edge of the hills, was discredited and we had to look for it further north, but as the scanty knowledge of the geology of the northern part of these hills gave no indication of any leading tectonic feature, there was nothing to guide us to a conjecture as to the exact position, and I was deputed to examine the Khasi and Garo Hills during the working season of 1897-98 with a view to the filling in of this blank. In spite of the limited time and the forest-clad nature of the country, which practically forbids any deviation from the beaten tracks, some important results have been obtained.

In the eastern part of the Garo Hills, and about the centre of the range, there are several pools which have been formed by a reversal of the slope of the stream beds. They vary in size, the largest being about 1½ miles long and 18 feet deep, the other smaller. In many cases these, so far as I could discover, did not owe their origin to a fault appearing as such at the surface, the stream bed has been elevated, or depressed, in a gentle roll, and as the streams flow in rock beds this must be due to a deep-seated deformation of the surface. Towards the northern edge of the hills I found some faults which appeared as such at the surface. Omitting the smaller ones, to which some doubt attaches, there are two principal ones: one at the Samin can be traced for about 2½ miles with a general direction of N. W. by W. and a maximum throw of 9 feet at the surface; the other in the Chedrang Valley has been traced for 12 miles before it becomes lost under the alluvium of the Brahmaputra valley at Jhira Hat. The throw varies largely and will fall from 20 feet to nothing within a few hundred yards; the maximum actually measured was 32 feet.

This fault in itself would be sufficient to account for an earthquake of the first class of magnitude, but it is only a small part of the cause of that of 12th June 1897. There are the other disturbances of the surface to be considered, and in assigning a cause to the earthquake we must either regard each displacement as the sign of a separate focus and the earthquake itself as a

compound one, consisting of a number of earthquakes which all occurred at once; or we may regard these surface displacements as themselves only secondary and indications of a more general and simple disturbance.

There is one, and so far as I can see, only one, supposition which would explain all the facts, and that is the existence, or the creation, of a nearly horizontal fracture or *thrust plane* along which the upper part of the earth's crust was pushed over the lower. This plane would nowhere come to the surface and the movement of the upper layer against the undisturbed crust beyond the limits of the fracture would give rise to just that compression which would account for the conspicuous displacements of surface levels seen in the eastern part of the Garo Hills District, and less conspicuously to the east and the west.

In this conclusion, we find an easy explanation of the area over which the shock had a maximum of destructive energy, without postulating an improbable depth for the focus. There is no necessity or reason to suppose that the thrust plane lies at any great depth from the surface, and it is possible that 5 miles may represent a maximum rather than a minimum value, but what the focus loses in depth it gains in area.

The eastern limit of this thrust plane extended to, but probably not much beyond the meridian of Shillong. To the west it probably extends under the alluvium of northern Bengal, perhaps as far as E. Long. 89° or a distance of about 180 miles. The breadth from north to south is 35 miles within the Garo hills, in the eastern part of the district, and to the north it extends under the alluvium of the Assam valley, possibly for as far again. These dimensions, 180 miles by 70 miles, must be taken as extreme limits, which is at present no reason to suppose were greatly exceeded. It seems certain that the thrust plane had its greatest width, and consequent greatest movement, in about E. Long. 91° or a little to the west, but permanent displacements of lesser extent have been recognised throughout the rock area within the limits mentioned. Outside the hills, in the alluvial plain, permanent displacements are marked by the surface disturbance of the alluvium and the extent of the epi-centre is largely a matter of inference; but the main conclusion is well established, that the origin of the disturbance was not confined to a spot or a line, but extended over a large area.

2. Surveys in the Madras Presidency.

Salem and Coimbatore districts.
C. S. Middlemiss.
T. H. Holland.

The survey of the Salem and Coimbatore Districts, which under Mr. Middlemiss's superintendence has been going on since December 1893, and which before that time had been conducted intermittently by Mr. Holland, should have been finished some time during 1897, but owing to the importance of the work, demanded another season to more or less finish it. Mr. Middlemiss will now prepare a detailed report on his investigation, which

were largely of an economic character, which report may be expected to be completed during the cold season of this year. Until Messrs. Middlemiss and Holland hand in their reports it is almost impossible to give a fair summary of their labours. The survey[1] could not be carried on systematically as in other parts of India, the nature of the work demanding constant changes from one special inquiry to the other, but I fully expect that the final result of the work will afford a valuable key to the interpretation of the rocks of Southern India, such as the Department has never obtained before.

Mr. C. S. MIDDLEMISS'S *work during the cold weather of 1896 to 1897.* Quartz, barytes rock.

The survey of the eastern part of the Tirupatur taluq, Salem District, which had been begun in December 1896, was continued during the first three months of 1897, and that of the Javadi hills has been continued. The most interesting result has been the discovery of a number of veins of a rock composed of quartz and barytes. The rock shows none of the parallel arrangement of the minerals usual in mineral veins, and has, in the field, all the appearance of an intrusive rock. Apart from its mode or occurrence which is that of a true pegmatite, there does not seem to be any ground for supposing that the barytes is a pseudomorph after orthoclase, and the field evidence points to the conclusion that the barytes was an original constituent of the rock, but whether the rock is an altered form of pegmatite or not, it is a remarkable and probably unique occurrence of barytes.

Trap-shotten gneiss.

In Messrs. King and Foote's memoir on the Salem, etc., districts (IV, p. 271) reference is made to a form of gneiss which has the appearance of being penetrated by a net work of veins of trap, to which the name 'trap-shotten' was applied. These rocks have been examined, and in the opinion of Mr. Holland the dark coloured veins are not due to the injection of basic trap, but to the partial fusion of ferruginous veins of hydrous minerals (epidote, etc.) by the heat produced during the movements by which the rock has been shattered along the lines where the 'trap-shotten' gneiss is found.

Allanite ?

A glassy looking mineral has been found in a dyke of pegmatite S. W. of Andiappanur. It is yellow brown in colour practically isotropic and has a sp. gr. of 3·45 in slightly altered specimens. Its characters have not yet been worked out, but it is almost certainly one of the minerals composed largely of the rare earths. Although it resembles tscheffkinite in appearance, its specific gravity more nearly approaches that of keilhauite and allanite.

Corundum.

The preliminary investigation of the corundum bearing rock near Palakod has been closed and a report submitted, which will be published in due course. Three lenticles have been found within a distance of 25 yards along the strike. From this it would

[1] During the course of the survey, besides the officers who were actively engaged on the work this year, Messrs. Warth and Smith were also employed on it.

seem that there is no lack of corundum so far as quantity goes. Two samples of 20lb. each, accompanied by samples of the rock, have been sent to the Imperial Institute, through the Reporter on Economic Products to the Government India, for valuation and report. Another sample has been sent to Messrs. Lyall, Marshal & Co., of Calcutta, who have kindly agreed to have the sample valued and reported on by their correspondents in America, and three samples have been sent to Messrs. Binny & Co., Perry & Co., and Dymes & Co., of Madras. On receipt of the reports on these samples it will be possible to judge whether there is any prospect of working the rock at a profit.

Iron ore.

In the course of the survey the iron ores of the Javadi hills were examined. The result shows that the upper parts of the ridge contain several beds of magnetite with hæmatite and quartz of the same general arrangement and appearance as those of the Kanjamalai and Tirtamalai. At the western base of the hills the mottled gneiss ascends about one-third of their height. Then comes hornblendic gneiss and a series of magnetic iron beds interbedded with hornblendic, micaceous, garnetiferous and hypersthene-bearing gneisses. These bands of iron ore all run N. N. E. and S. S. W. parallel to the run of the ridge and are marked by prominent ridges and platforms standing out from the slopes. The lowest and most prominent, about 100 feet thick, has been traced from Monellimalai near Pudur to Methamalai, S. E. of Alangayam—a distance of 16 miles—and a large number of specimens have been taken for analysis and distribution.

Elæolite-bearing rocks.

After a short recess season, field work was resumed in the Coimbatore district on 18th June 1897. In the neighbourhood of Kamgayam, elæolite-bearing rocks have been found, containing crystals of elæolite 3 or 4 inches in diameter. The prevalent rock is described as fine grained and darkened in colour by the abundance in it of magnetite, graphite and ferromagnesian silicates, amongst which biotite and hornblende are the prevailing forms. This rock is cut through by coarse grained veins composed of elæolite and felspar with smaller quantities of graphite biotite and green apatite. Mr. Holland regards this rock as genetically connected with the corundum of Kangayam. He refers to Morozewicz's artificial production of corundum by the devitrification of slags containing over 30% of alumina and rich in alkalis; and points out that the elæolite contains over 33% of alumina, and is in great excess amongst the rock constituents.

The quartz-magnetite schists near Uttukuli and Viziamangalam Railway stations were examined and found to be associated with calciphyres and pyroxenic and garnetiferous granulites. Similar schists are associated with hornblende-norite at Madukarai, 7 miles south of Coimbatore, where the well known coccolitic marbles appear to be associated with pyroxene scapolite granulites similar to those associated with the ruby-bearing limestones of Burma.

Mr. Middlemiss was principally engaged in the survey of the neighbourhood of Coimbatore. He finds the lowest-lying rocks of the region to consist of a well foliated gneiss composed of quartz felspar and black mica. The foliation of this rock is bent into two long and gentle anticlines with a shallow syncline between them. On either hand to the north and south they pass under a series of basic and ultrabasic rocks which again pass upwards into normal charnockites. Lambton's peak near Coimbatore, lies on a sharp syncline; the lower slopes are formed by the more basic members of the charnockite series, while the higher crags are composed of paler coloured and more acid members of the same series of rocks.

Mr. Holland was engaged in the examination of the neighbourhood of Salem and part of the Shevaroy hills. The Shevaroys are composed of rocks of the charnockite series, principally the intermediate type which form the bulk of all the larger exposures; a trap dyke can be traced in a north-west to south-easterly direction right across the hills, but becomes lost on reaching the schists of the Salem-Atur valley. Seven miles off to the south-south-east a dyke of the same rock running in the same direction is found, but the continuation would lie 3½ miles to the south-west of the Shevaroy dyke. It is doubtful whether these can be regarded as continuations of the same dyke, broken by faulting, and it is more probable that they are independent dykes of the same composition.

On the west side of the Shevaroys Mr. Holland finds the normal charnockite abruptly cut off and replaced by the varied rocks of the low ground, amongst which the most prominent forms are highly garnetiferous hornblende pyroxene granulites. The line of separation is probably a fault, which runs northwards from Salem towards the chalk hills, and Mr. Holland suggests that it probably determined the precise locality of the peridotite outbursts of that area. It may also be suggested that this fault line may be genetically connected with the elevation of the Shevaroy hills, and that they may owe their existence, in part at least, to special elevation, and not solely to the greater resistance to denudation offered by the rocks of which they are composed:

Mr. Middlemiss's *work during the cold weather, season 1897 to 1898.*

Animallai hills.

Hornblende-biotite gneiss.

Horizontal or gently undulating strata.

Porous soil.

(1) First part was spent in the southern parts of Coimbatore district in the difficultly accessible parts of the *Animallai hills*, which were entered along 3 lines, giving 3 cross sections. Owing to dense forest the work was difficult and slow. The results showed that these hills do not in the least resemble the Nilgiris geologically, being composed for the most part of a very *quartzose hornblende biotite gneiss* well foliated, in great horizontal or gently undulating beds forming magnificent *scarps* and *plateaux* above, the latter of which at elevations of 3,000—4,000 feet are now being extensively

opened out for coffee planting. From the fact that the rock is different from that of the Nilgiris and weathers into an extremely light porous soil I anticipate a great success to the planting community.

Augite and hypersthene gneiss.

Only a few minor layers in the gneiss yield a little *augite*, and *hypersthene* veins of pegmatite occur, but no basic dykes are found in this part of the country.

Kanjamallai Iron Ores.

(2) Examined the *Kanjamallai* hill near *Salem*, for the purpose of selecting *2 tons iron ore* for despatch to England (see special report sent in).

Railway cutting, etc.

(3) *Railway cuttings* between Coimbatore and Sankaridrug examined by trolly.

(4) Sethurama Rao, the native assistant of the party, finished mapping some parts near Kaveripuram and the hills N. E. Sankaridrug. S. Rao had accompanied Mr. Middlemiss for about two years as an assistant, temporarily employed, and he seems to have shown great zeal and usefulness in certain details of work.

Mr T. H. Holland, *Work during the seasons 1896 to 1897.*

As a result of his investigation in the Salem and Coimbatore districts of Madras, Mr. Holland has compiled three reports :—

1. The Charnockite series of South India.
2. On an elæolite-syenite containing graphite, and associated with corundum. in the Coimbatore district.
3. The geology of the Shevaroy hills and the neighbourhood of Salem

The following is extracted from these papers :—

Mr. Holland *on the Charnockite series of South India.*

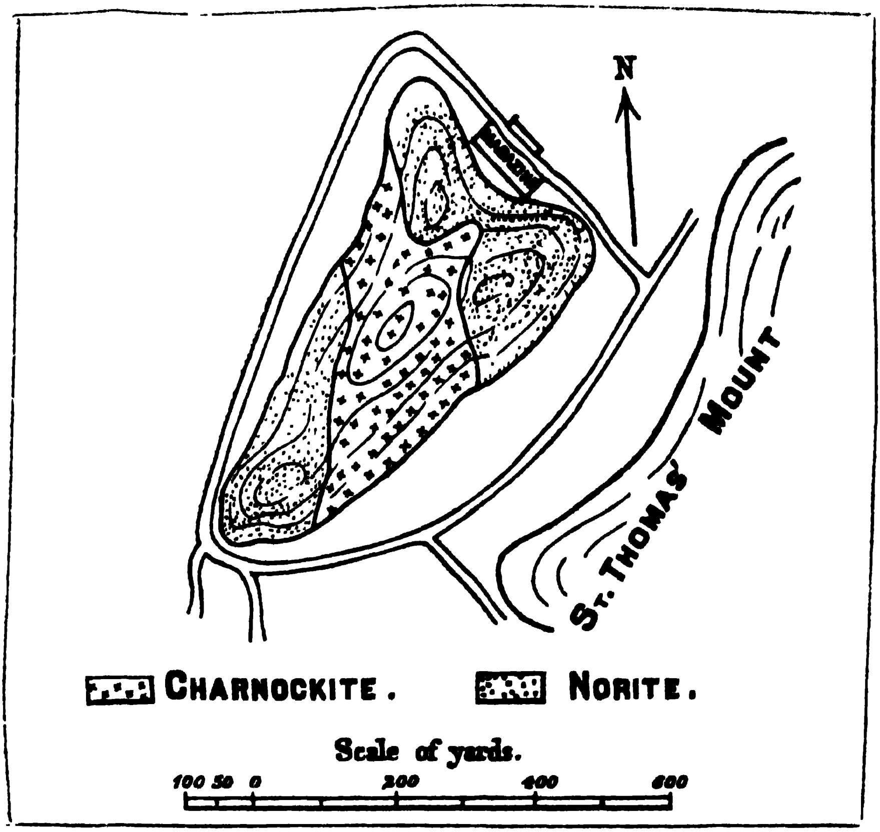
"I have prepared a memoir on the charnockite series of South India giving a detailed account of the microscopical and chemical characters of the normal as well as the altered varieties, together with an account of their leading field characters and the scenery of the areas in which they are so largely developed. The rocks which are grouped together under this name constitute the largest formation in the crystalline schists of the Madras Presidency, forming besides numerous small hills, the main mass of the Shevaroys and Nilgiris, with a portion, at least, of the Polnis, and the Travancore ghats to Cape Comorin. Similar rocks are known in Burma, Ceylon and again in Madagascar ; in fact, they must have constituted the protaxis of the old pre-cretaceous continental ridge connecting India and Africa.

In the field, as well as under the microscope, these rocks present a striking individuality, which enables the worker to separate them at once from the other groups of gneisses. The one constant feature throughout all varieties is the presence of hypersthene amongst the mineral constituents. They vary in composition from acid types, containing 75 per cent. of silica, to

ultra-basic pure pyroxene rocks, containing only 48 per cent. of silica. The leading varieties are, in order of descending acidity :—

(1) Charnockite, or hypersthene granite.
(2) "Intermediate" or mixed forms.
(3) Norites.
(4) Pyroxenites.

The type mass selected for *charnockite* is the central portion of the hill south of the powder magazine near St. Thomas' Mount, Madras. The mass selected for the typical *norite* of this series forms the flank of the same hill. The "intermediate" varieties are typically developed in the Shevaroy hills where the rocks have an average specific gravity of 2·775, and a composition equivalent to about one part norite to three parts charnockite. The typical masses of pyroxenite form narrow dykes in the hill near Pammal village, west of the railway station of Pallavaram, near Madras. Specimens of each of these types are preserved in our Museum and will be supplied also to the Madras Museum.



Map showing Type Masses of CHARNOCKITE and NORITE, near St. Thomas' Mount, Madras.

The nearest foreign equivalents of this group of rocks are those known to the German geologists as "pyroxene-granulites," well known from the Saxon occurrences, and to the French geologists as "pyroxene gneisses" which are well developed in Brittany. The norite groups of Scandinavia are also probably the same, and from these Professor Vogt in 1893 described, as a new type, a hypersthene-granite precisely similar in composition to our charnockite, whose discovery was announced in our *Records* at the end of 1892.

Before the microscope was employed in Indian geology, the older members of the Survey had fully recognised the peculiar field characters of this group, and referred them to the younger (upper) division of the gneisses in contradistinction to the more granitoid types which were considered to be older. All recent researches tend to confirm this view, which is in agreement with the classification of similar rocks in France, Scandinavia and America.

But the older ideas concerning the origin of these rocks probably needs revision. Following Lyell, most of the old geologists considered the banding and foliation of the gneisses to be evidence of their sedimentary origin, but as precisely the same structures have now in several instances been found in undoubted eruptives, even of tertiary age, the banding and foliation structures can no longer be regarded as reliable evidence, and the origin of each group of gneisses must depend on its own local features. With regard to the charnockite series the chemical composition, mineral characters, and many of their structures are completely paralleled amongst well known igneous rocks, whilst no sedimentary rocks are known to present these characters. In addition to this, narrow dykes of these rocks have recently been found in Coorg showing the characteristic basic and chilled selvages of igneous intrusions. It is concluded, therefore, that though this group of rocks may still be retained in their old position amongst the gneisses they must be considered to be igneous rocks erupted into still older gneisses.

Mr. R. Bruce-Foote, late Superintendent in this Department, who has made a more extensive field study of the South Indian crystallines than any other geologist, agrees with this retention of the group in its old-established position amongst the upper gneisses, and also with this revision of our opinions as to the nature of its origin.

Geology of the neighbourhood of Salem.

The rocks examined near Salem last August form the following groups :—

(1) Quartz-rock.
(2) Augite-diorites (diabases) and augite-norites with micro-pegmatite.
(3) Peridotites.
(4) Charnockite series.
(5) Biotite gneisses, thinly foliated "leaf-gneisses," and quartz-magnetite-hornblende schists.

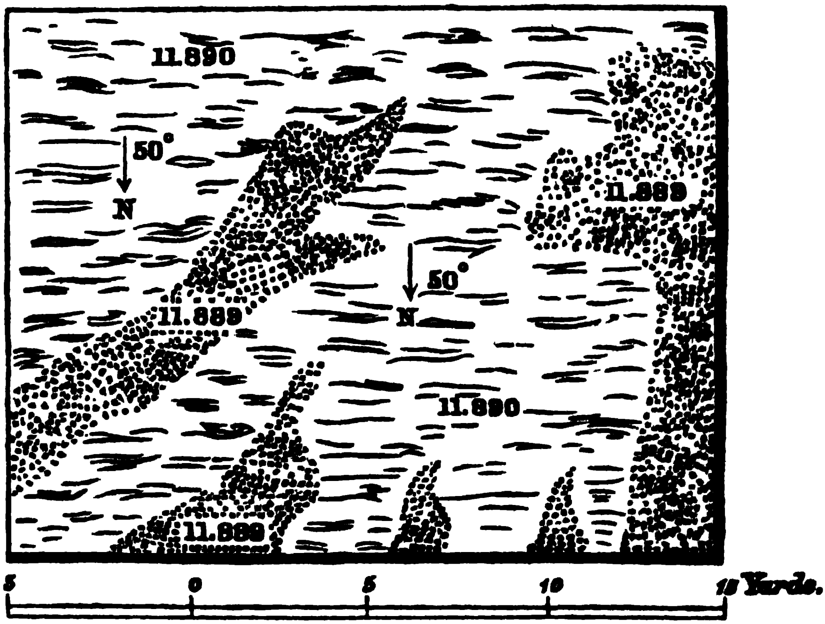
The great masses of quartz forming the "white elephant rocks" on the southern slopes of the Shevaroys were found, on microscopical examination, to contain numerous cavities filled with liquid carbonic acid, such as are

usually found in intrusive veins of quartz. This confirms Messrs. King and Foote's conclusions as to the origin of these great isolated masses of quartz* (Mem., G. S. I., Vol. IV, p. 339).

The exposures of group 2 completely resemble in characters the corresponding types already described in my papers on the South Indian dykes (Records, G. S. I., Vol. XXX, p. 16 and Quart. Journ. Geol. Soc., Vol, LIII, p. 405). The "Chalk Hills" area was described by King and Foote in their memoir to accompany sheet 79 of the Indian Atlas. The rocks were found by me in 1892 to belong to the family of periotites (Records, G. S. I., Vol. XXV, p. 143), and further details concerning the magnesite were published by Mr. Middlemiss in 1896 (Records, G. S. I., Vol. XXIX, p. 31).

The charnockite series forming group 4 consist of the "intermediate" varieties, augite norites of the ordinary kind, as well as of a coarse garnetiferous form, and pyroxenites. The last two varieties form lenticular masses in, and are considered to present intrusive relations to, the members of group 5.

The Shevaroy Hills form a good typical example of a large mass (covering 100 square miles) composed almost wholly of the "intermediate" varieties of the charnockite series. Here, as usual, these rocks present the common internal features of a great igneous massif in the presentation of basic *schlieren* and of acid contemporaneous veins. The average specific gravity of 48 specimens taken from different parts of the hills is 2·775.



Plan showing tongues of unaltered CHARNOCKITE 11. 889 corroding highly crushed BIOTITE-GNEISS 11·890.

In quarry, 3½ m. S. of Salem on the Namakal road.

(The figures indicate the numbers of the specimens in the Geological Museum, Calcutta.)

The most important member of group 5 is the biotite-gneiss, because its peculiarities are so exactly preserved in some gneiss pebbles of the Dharwar conglomerates, whose origin can thus, as far as petrological correlation permits, be determined.

Besides the evidence of the lenticular masses, the relative ages of this rock and the charnockite series are determined by a very interesting exposure south of Salem. These tongues of charnockite, protruding from the large mass forming the Jarugamalais, are seen to transgress across the foliation planes of the biotite-gneiss, and whilst the charnockite tongues imperfectly psendomorph the old structures of the biotite-gneiss, the former are quite fresh and unaltered, whilst the latter rock is crushed, and its constituents greatly changed. The charnockite must, therefore, have attained its present position by transgression after the consolidation, and even crushing, of the older biotite-gneiss.

Elæolite-syenite with graphite in Coimbatore.

The elæolite-syenite of Sivamalai in the Coimbatore district is found to include the following chief types:—

(1) A foliated variety containing graphite and biotite—the prevalent type.
(2) Coarse grained contemporaneous veins cutting through (1), and composed principally of elæolite and microperthite in crystals sometimes four or five inches across.
(3) A granulitic form devoid of graphite but containing microcline and plagioclase.
(4) A mottled variety in which hornblende has partly replaced the biotite and is accompanied by calcite.
(5) Basic lenses composed principally of hornblende with calcite, elæolite and smaller quantities of the other ordinary constituents.

As is the case in the typical occurrences of this remarkable group of rocks, the elæolite-syenite of Sivamalai is accompanied by large masses of augite-syenite which, like the typical laurvikite of South Norway, contains olivine.

The peculiar features revealed by these groups of rocks are of very great interest in their bearing on petrological problems which have recently come into prominence: in the first place, elæolite has never been found amongst the old crystalline schists, but is always found as a constituent of undoubted eruptive rocks. At the same time graphite has always been considered to be a typical constituent of metamorphic rocks, its occurrence in which has been supposed to be proof of their sedimentary origin, whilst it is not known in unequivocal igneous rocks. But in Sivamalai these two minerals, elæolite

and graphite, are found together as evenly distributed and essential constituents of the same rock-mass. As all the other evidences, chemical composition included, point to the similarity between this rock and the known elæolite-syenites in other parts of the world, the Sivamalai mass must be considered to be of igneous origin, in which case, whilst we have to revise our ideas concerning the nature of graphite, the presence of this mineral in the elæolite-syenite adds another variety to this group, every occurrence of which presents a peculiarity of its own.

Accepting the conclusion that this elæolite-syenite agrees with all other occurrences of the rock in being of igneous origin, the peculiar features which it here presents, throw great light on many other problems in the crystalline area of South India. Some of the members, for instance, of the charnockite series (which constitutes probably the largest formation in South India) have been found to contain graphite which hitherto has appeared to be in conflict with the many evidences pointing to the igneous origin of these rocks. Another difficulty that may now be removed is the constantly granulitic structure of the lenticular masses so common in the Archæan gneisses: these lenses of elæolite-syenite present a similar granulitic structure and foliation; but in some cases the peculiar interlocking of constituents in igneous rocks has been preserved, whilst where slight deformation has occurred the branched crystals are found to be dislocated, though still preserved in groups, and presenting a true granulitic structure. The granulitic structure thus remains no longer a difficulty in the lenticular masses which in mineral characters and chemical composition completely resemble known igneous rocks.

But the most important feature in connection with this discovery of elæolite-syenite is the bearing it has on the origin of the corundum associated with it. The corundum is found in a felspar rock which invades the elæolite-syenite in the neighbourhood of Sivamalai, and is worked by the villagers at or near the junction of the two rocks. As the elæolite-syenites contain a higher percentage of alumina than any other known igneous rocks, it is natural to look to it as the source of the excess of alumina which has crystallized out near the junction as pure corundum. The observation is all the more interesting because corundum, precisely similar in crystallographic characters to that near Sivamalai, has been prepared artificially by simple fusion of the mineral elæolite.

All other occurrences of elæolite-syenite have been characterised by the occurrence in it and the associated rocks of minerals containing the rare elements. No exhaustive chemical investigation of the Sivamalai rocks has yet been undertaken, but it is not likely to prove an exception to the rule, and indeed two or three minerals have already been found in these rocks

* Hautefeuille and Perry; Bull. Soc. Min. XIII, p. 147, 1890.

which cannot be referred to any well-known species, and therefore cannot at once be identified.

General considerations.—Two very interesting points arise out of our recent study of the Madras crystalline rocks :—

(1) The remarkable abundance of the mineral pyroxene, and,

(2) The great freshness of minerals like olivine and elæolite which in Europe are almost always badly decomposed, even in rocks of comparatively young geological age.

The first point is in agreement with our now well-established conclusions as to the long period of quiescence which peninsular India has enjoyed since lower palæozoic times; for the pyroxenes are amongst the most susceptible of all minerals to dynamo-metamorphism. The second point arises naturally out of the first and indicates that, except in the immediate neighbourhood of the coast, the Madras Presidency has probably never since Cuddapah times been depressed below the sea-level, but on the other hand has undergone uninterrupted denudation, with the result that relatively deep portions of the crust have been brought to the surface. It is this exposure of the very deep-seated rocks by a continual denudation probably unequalled, except in the remarkable protaxis of Canada, that has revealed to us a set of rocks in Madras quite unfamiliar to our European experience; amongst these the quartz-barytes rock discovered during the past year in Salem and the elæolite-syenite, now described from Coimbatore, are unique types.

The following summary of field-work in Coorg has been sent in by Mr. Holland who was in charge of the survey: field-work commenced on the 1st December last, and has continued without interruption up to the present date. Previous to this survey of Coorg no information of any kind concerning its geology was available.

COORG.
Mr. T. H. Holland and Dr. T. L. Walker.

I.—Petrography.—Except the alluvium and laterite, which cover considerable areas, no unaltered aqueous rocks have been found. Of the crystalline rocks the following groups have been mapped and their leading features determined :—

(1) Biotite-gneisses.
(2) The Mercara group.
(3) The charnockite series.
(4) The central granite-group.
(5) The norite "stock" of Watekolli.
(6) Dharwars.
(7) Basic and ultra-basic rocks intrusive since the close of the N.W.-S.E. system of foliation.

(1) The *biotite-gneisses* are similar in character to those generally considered to represent the older (lower) division of the gneisses and require no special mention.

(2) Under the name *Mercara group* I propose to distinguish a belt of thinly foliated gneisses and schists forming the Mercara plateau, and stretching in a N.W. to S.E. direction along the centre of Coorg. The most remarkable feature in connection with this group is the enormous abundance of the mineral kyanite, which is usually comparatively rare. Sometimes there are bands of almost pure kyanite, whilst at other times it is associated with quartz, biotite, graphite, purple garnet and rutile. Towards the south-east end of the belt occur exposures of a very handsome variety, composed of deep-blue kyanite, in crystals two or three inches long, with chrome-green euphyllite and a small quantity of quartz. With the kyanite-schists which form the predominant type, there occur garnetiferous biotite-gneisses and quartzites in subordinate quantity. Bands and lenticles of green amphibolite and veins of pegmatite are very common. The latter sometimes contain large mica crystals. Although the characters of this group are in general agreement with those which usually mark the younger (upper) division of the gneisses, the great abundance of kyanite distinguishes it from any other formation so far described in India. It is interesting to note that the distribution of the Mercara group is roughly coincident with the most productive belt of coffee plantations.

(3) The *charnockite series* flank both sides of the Mercara group and present the normal characters displayed elsewhere in the south of India. Several interesting exposures have, however, been found which throw great light on the origin of this group of rocks. On the N.E. side of Coorg the large masses are fringed by numerous bands of the intermediate and basic varieties, running like dykes through the surrounding biotite-gneiss, and generally, but not always, parallel to the foliation of the latter. Careful examination of some of these show that they are more compact and basic at the selveges than in the centre of the bands, and microscopic examination shows that the marginal portions are more hornblendic, a feature which characterises the border facies of similar pyroxenic intrusives elsewhere. At the same time, these dykes, as they must now be recognised to be, contain the essential and usual constituents of the charnockite series, presenting their characteristic habits, and, like the larger masses, often contain garnets. It is interesting to find that these marginal portions of the dykes agree with the basic, fine-grained secretions of the larger masses in being more hornblendic than the average type, both

being the products of early consolidation in their respective intrusions. Taken into consideration with the phenomena noticed last year near Salem, where tongues of unaltered charnockite were found corroding a highly crushed gneiss, the dykes recently found in Coorg may be regarded as conclusive evidence in favour of the intrusive nature of the charnockite series. Though these recent observations necessitate a change in our views concerning the *origin* of these rocks, they tend only to confirm their *position* in the classification of the Archæan rocks adopted in the earlier days of the Geological Survey and recently repeated by Mr. Foote in his memoir on Bellary.

(4) A large stock of *porphyritic biotite-granite* crops out in the centre of the belt of Mercara schists, and further exposures of the same rock have been found to the south-east, near one of which was discovered a felsitic form with bi-pyramidal phenocrysts of quartz. The granite must have consolidated before the completion of the N.W.-S.E. system of folding was complete, and consequently it shows the characteristic strain-slip cleavage with slickensides lubricated by crushed mica—the result of crushing after consolidation. Except at some points on its western border, where it is limited by a (probably faulted) junction with the Mercara group, there are practically no exposures sufficiently clear to settle the relations of the granite to the other rocks. Near its margin, however, masses of sillimanite-gneiss have been found in the granite and probably represent a contact product due to alteration of the kyanite-schist, which would be a perfectly normal occurrence. So far as it goes, then, this evidence points to the granite being younger than the Mercara group.

(5) The large mass of *norite* at Watekolli forms a distinct addition to Indian petrology. The crystals, sometimes an inch or two long, of pink labradorite and schillerized pyroxene make a very handsome rock. Besides the coarse-grained forms, there is a compact, granulitic, marginal facies, containing hornblende, which is extremely difficult to distinguish from the basic forms of the charnockite series, the similarity being accentuated by local foliation. This rock must have been erupted near or after the close of the earth-movements which foliated the rocks of the western Ghâts.

(6) Hornblende-schists and quartz-hematite schists similar to those of the *Dharwar System* form two very small strips in the extreme north of Coorg. They are cut through by both systems of basic

dykes, and are foliated as well as banded with apparent conformity to the biotite-gneiss.

(7) Next in order come the *basic and ultra-basic intrusives*, which show no foliation and sometimes form dykes at wide angles to the youngest fold-axis. The *ultra-basic* types include, besides some fine masses of pyroxenite, exposures of dunite (olivine-rock) and picrite, the former being decomposed after the fashion of the well-known occurrence of the "Chalk Hills," Salem, with the formation of magnesite and serpentine. The *basic* dykes form two principal groups: one group shows considerable progress towards the formation of epidiorites by granulation of the felspars and granular amphibolization of the pyroxenes. These form a N.S. series of prominent dykes in the N.E. corner of Coorg and represent an old eruption, probably of the Dharwar age. The others are remarkably fresh rocks, composed of augite and felspar in the south, but containing also olivine in the northern occurrences. One fine dyke of this group runs in a W.S.W.-E.N.E. direction completely across Coorg, approximately agreeing with the boundary line of the low-lying taluk of Kiggatnád, and almost, though not completely, separating the basin of the Cauvery from that of the Lakshmantirtha. These large dykes of very fresh basic rock are probably the underground representatives of the Deccan trap.

II.—Structural features.—The general direction of the foliation of the younger schists throughout Coorg is N.W.-S.E. or N.N.W.-S.S.E., that is, parallel to the direction of the western Gháts and of the Malabar coast-line. Our observations thus fall in with the evidence obtained by Mr. Foote as to the parallel folding of the Dharwar strips in western Mysore, and shows that, whilst the present contours may have been determined by the uninterrupted, geologically-long course of denudation, the leading features are, as in young mountain ranges, still coincident with the final system of folds. As one result of this N.N.W.-S.S.E. folding, the rocks in Coorg frequently show dislocations in the E.N.E.-W.S.W. direction which have determined the position of some of the younger dyke-rocks. In some cases the unequal folding on opposite sides of these transverse dislocations has resulted in horizontal displacement of the beds. The general dip of the foliation planes is towards the S.W.; it will be interesting now to find from the South Canara side whether the much steeper western face of the Gháts is the result of an opposed dip with the production of a synclinal fold and scarp face, or the mere effect of exposure to the unchecked force of the monsoon.

III.—Economic Minerals.—Graphite has frequently been found disseminated through the rocks, but so far has not been observed in any concentrated form.

The discovery of pegmatites amongst the Mercara group led to a careful search being instituted for mica, with the result that in five or six localities sheets, well beyond the marketable size, have been obtained. The largest were obtained on Elk Hill, where from immediately under the soil, sheets free from warping and measuring some 30 inches across, were removed from the outcrop of the vein. All samples show a high degree of elasticity and good colour, but much of the material will have its value depreciated by ferruginous inclusions between the cleavage-planes, whilst some of the mica is badly warped. As to how far these defects reduce the value is now being ascertained in the London market.[1] It is extremely unlikely that the best veins have been the first to be "struck" in an area so completely soil-covered but enough has been shown to prove that the mica-bearing pegmatites extend over a wide area, and will probably be a source of sensible profit if worked with discretion.

The occurrence of the younger division of the gneisses at once suggested a search for limestone, which is specially in demand for the coffee plantations, but so far no trace of the rock has been observed.

Linga Raja who built the palace at Mercara in 1812 has set the example of utilizing the diabase dykes for ornamental architecture; but the large slabs which he secured could only have been obtained from such a close jointed rock by an enormous expenditure of labour. This rock is still much used for mill stones and mortars. There is a mass of coarse potstone to the south-east of Mercara, which might easily be turned into vessels, but has not apparently been worked.

3. Bombay Presidency.

Lala Kishen Singh.

The country north and north-east of Ahmadabad in the Gujarát province, to the Mahakántha States was reconnoitred during last field-season by Lala Kishen Singh with the special object of defining the alluvial areas from the older rocks, which form the south and south-western extensions of the Aravalli ranges. No detailed report is at present available, but it may be expected that the results of the reconnaissance will not be of a very startling character, as is shown by the monthly diaries of work sent in already.

4. Western Rajputana and South-Eastern Marwar.

Mr. T. H. D. LaTouche.

A great deal of geological survey work was accomplished in former years in Western Rajputana; Messrs. W. T. Blanford and Hacket have already described much of the country

[1] Since this report was written, an answer has been received from London, which shows that the defects mentioned do not materially lesen the marketable value of the mica, which will fetch very good prices at home.

around Jodhpur, but many of the more or less isolated hills which stand out of the sand-covered plain of Rajputana were geological blanks on our maps.

Season 1896 to 1897.

Mr. LaTouche was engaged during the seasons 1896 to 1897 on a detailed survey of that country, and during that season accomplished to fill in the geology between Jodhpur and the higher hills south of the Luni river, on which country he has sent in an interesting progress report, fully illustrated. I quote his summary:—

General features of the country.

By far the greatest portion of the country with which this report deals is covered with blown sand and alluvium, forming broad stretches of more or less level plain, diversified by low sand-hills, and when the seasons are favorable, bearing excellent crops, principally of millet. At intervals in this plain isolated rocky hills rise abruptly from it, looking as though they were the peaks and ridges of some great mountain range, the lower slopes of which have been smothered in sand. The largest of these hills are found in the Siwana district to the south of the Luni river, where one mass, called the Saoru range on the map, reaches an altitude of over 3,000 feet above the sea, and another rises to between two and three thousand. All the rocks found in this region with the exception of a small area in the extreme north-east, in the immediate neighbourhood of Jodhpur City, are of various crystalline types, including ancient lavas, rhyolites and felsites with intercalated bands of tuff ashes and breccias, to which the name of 'Malani series' was given by Mr. Blanford, intrusive dykes of diorite, and intrusive granites probably belonging to two distinct periods, one containing much hornblende and no visible mica, the other with both hornblende and mica in microscopic crystals.

The Malani series.

In spite of the great age of the rocks belonging to this series, and the great alteration which they have undergone, there is clear evidence, that when originally formed they were true volcanic ejectamenta spread out over the surface of the country and probably subærial. All the well-known characteristics of glassy rocks can be observed in the lavas. Some of the flows show beautifully developed flow structure and may be called rhyolites. In some of them the original glassy texture has hardly undergone any alteration, so that a thin slice remains almost dark under the microscope between crossed nicols. Sphærulitic and perlitic structures occur in other cases, and some of the flows are vesicular. Moreover, in many places the lava flows are interstratified with tuffs, ash beds and breccias.

Conglomerates associated with lava flows.

That the volcanoes were subærial is proved by the fact that beds of shingle composed to a large extent of the waterworn debris of the volcanoes themselves are found in several places interstratified with the lava flows. These

could not have been formed in deep water, since the pebbles are sometimes of considerable size, but were washed down by streams flowing over the surface of the lava beds, and they show that denudation of the surface was going on during the period of volcanic activity.

Possible vent at Nagona.

No undoubted indications of the position of any of the vents through which the lavas were poured out have yet been found. This is not to be wondered at when we consider how large a portion of the region is concealed by sand. At Nagona, however, about 33 miles to west-south-west of Jodhpur, the existence of a vent is conjectured from the presence of a mass of rhyolite felsite, in which the lines of flow are vertical, causing the rock to split into thin plates resembling shales. The fissile structure may have been imparted to the rock by pressure from the sides of a fissure through which it was erupted. The vent, if it was one, appears to have been in the form of an elongated fissure, the longer axis of which runs from south-east to north-west. On either side of this locality the lava flows were observed to dip away from it in opposite directions, and there may have been a true volcanic vent here, but it seems more likely from the absence of any general arrangement of the lava flows in a conical form, that the eruptions were of the fissure type.

Age of the Malani series.

The exact geological age of the Malani series is still undetermined, because they have as yet been nowhere found in contact with rocks whose exact horizon is known. They are certainly much older than the sandstones which rest upon them at Jodhpur, which are conjectured to belong to the upper Vindhyan period, for a conglomerate largely made up of rolled pebbles and boulders of the Malani lavas, mingled with other crystalline rocks, is found at the base of the sandstones. So far they have not been found in contact with any of the rocks of the Aravalli series, and their relation with the latter are still uncertain.

Intrusive dykes; diorite.

The lava flows, at some time since their eruption, and after the development in them of joint planes, were invaded by dykes of a basic rock, containing plagioclase felspar and hornblende, which broke through them along the lines of jointing, the majority running due north and south. The dykes are usually much decomposed and are more easily weathered than the felsites, so that they lie in trenches between vertical walls of the latter. They are most common among the hills to the south of the Luni, especially in the range of hills about 6 miles south-west of Belotra, and only one was found to the north of the river, near the villages of Samdari.

Hornblende granite.

Subsequent to the intrusion of the diorite dykes, huge bosses of granite, very coarse in texture and composed of quartz orthoclase felspar and hornblende, were forced in among the felsites, probably along the axes of the folds into which these rocks had been thrown. Wherever the two rocks are found in contact, the granite

throws off ramifying and interlacing veins among the felsites, and the latter, with the associated beds of tuff, are sometimes altered at the point of contact. The granite forms the greater part of the Suora range, the largest continuous mass of rock in the country. The distributions of the granite bosses is somewhat peculiar. They lie along a fairly continuous ring, interrupted for any considerable distance only on its north-west side, measuring roughly 19 miles in diameter from east to west, and 16 miles from north to south. Towards the centre of this ring the granite does not appear anywhere at the surface. The arrangement suggests that the lines of weakness along which the granite was protruded was circular in plan, and may have had some connection with the roots of a volcano. There is nothing however in the disposition of the felsite flows and ash-beds to bear out this suggestion, but they have been disturbed by folding, as is shown by the present inclination of the pebble beds interstratified with, which must have been laid down on a more or less horizontal surface, so that their original arrangement has been marked by subsequent earth movements. Although the granite has in some cases pushed aside the lava flows, in many other instances it has evidently invaded and absorbed them, since the flows can be seen to dip towards or strike against the steep sides of the granite bosses.

Age of the Granite.

That the hornblende granite is younger than the diorite dykes is proved by cases in which veins from the granite penetrate the dykes, and also by the fact that the diorite is never found intrusive in the granite, though it sometimes runs up into contact with the edges of the latter.

MR. LATOUCHE. Season 1897-98.

Summary of Observations, Season 1897-98.—The ground surveyed and mapped this season comprises an area of about 2,000 square miles, lying to the south and south-east of that dealt with in my report for last year. The general features of the country are very similar, the greater part of it being covered with blown sand and alluvium, through which solid rocks protrude in patches of greater or less extent, forming rugged hills and ridges isolated from each other—a structure which makes it very difficult, and often impossible to trace the boundaries of the various formations. A portion of the ground had already been surveyed and mapped by Mr. Hacket, but in the only published account of his observations,[1] he gives very few details of the relations of the rocks to each other.

The principal object was to discover if possible the relations between the Malani volcanic series and the Aravalli rocks. Mr. Hacket mentions one locality in which the Malani rocks rest upon rocks of a different type,[2] and two in which they are seen very close to each other. The first mentioned

[1] Records, G. S. I., Vol. XIV, Pt. 4.
[2] *Idem*, p. 302.

locality is about 8 miles to the north of Chanod, and here the evidences of unconformity between the two formations seem to be clear, for not only is the strike and dip discordant, but in places a bed of coarse conglomerate containing rolled fragments of schist and slate derived from the lower beds is intercalated between them. Mr. Hacket was in doubt as to whether the slates and schists here were Aravallis, but there seems to be no difference between them and some slaty beds which occur in close proximity to a ridge of Malanis near Chotila, about 8 miles further north, which Mr. Hacket considered to be undoubted Aravallis. They are certainly in a much less metamorphosed condition than the schists found in the plain to the west, but it may be suspected that a fault of considerable throw must occur along the eastern edge of the area occupied by the Malani rocks, running in a general north-east to south-west direction. No outliers of the Malanis occur, so far as known to the east of this line.

Excluding the Aravalli schists, slates and quartzites, the whole of the rocks in this area were mapped by Mr. Hacket as gneiss, but it was found that although some of them may be described under that name the greater portion consists of true granite and that this can be referred both on lithological and stratigraphical grounds, to two distinct periods. The older granite which is typically developed in the neighbourhood of Erinpura, is an exceedingly coarse-grained rock, the crystals of felspar reaching a length of 3 inches or more. It is intrusive in the Aravalli schists, but was intruded prior to the movements which resulted in the folding of those rocks, so that it frequently exhibits a well developed gneissose structure, especially near the juncture with the schists, the felspar crystals being drawn out into 'eyes' surrounded with mica The veins which it sometimes throws off into the schists have also been contorted and crushed. The newer granite, on the other hand, is not so coarse-grained, generally contains red felspar and a considerable proportion of hornblende as well as mica, and never exhibits any trace of a foliated structure. It forms a series of isolated hills and bosses, extending from near Jodhpur along the eastern edge of the Malani area to the town of Jalor, about 70 miles south-south-west of Jodhpur and 30 miles west-north-west of Erinpura. It is intrusive in the Aravalli schists, and also in the Malani volcanic rocks, wherever it occurs in contact with them. The form of these granite bosses, their distribution, and their relations with the lavas, all suggest that they may occupy the vents from which the latter were poured out.

All these rocks, including the Aravallis, are traversed by a system of dykes of basic rock, diorite, varying in direction from about north-north-west to west-north-west. They occasionally reach large dimensions, as in the hill at Jalor, where they break through the red granite, and in two cases at least are quite 200 feet wide. The rock of which they are composed usually

weathers more readily than the surrounding rocks, so that narrow chasms with vertical walls on either side are formed, and they are frequently found on the crests of narrow passes through the hills.

The two granites mentioned above are distinguished from the hornblendic granite described in last year's report as intrusive in the Malani series further west, in the district of Siwana, by the fact that the last contains no visible mica, and moreover has been intruded into the Volcanic rocks subsequently to the intrusion of the diorite dykes, which are never found piercing it.

For the sake of reference it is proposed to adopt the following names for these granites provisionally, commencing with the oldest:—

1. Erinpura Granite.—Forms a large spread to the north and east of the station of Erinpura, and extends beyond the limits of the area surveyed. Typically a very coarse-grained granite, with large crystals of white or grey felspar up to 3 inches in length, quartz and mica. Intruded into the Aravalli schists prior to their disturbance and folding, and near the junction frequently assumes a foliated structure.
2. Jalor Granite.—Forms a series of bosses extending from near Jodhpur along the eastern edge of the Malani area to Jalor and probably further south into Sirohi. The large hills in the neighbourhood of Jalor are mainly formed of it. Generally a rather coarse-grained granite containing red or flesh coloured felspar, quartz, mica, and hornblende. Intrusive in the Aravalli rocks and in some portion of the Malani volcanic rocks, and traversed by diorite dykes.
3. Siwana Granite.—Forms the greater part of the high range immediately to the south of Siwana, and occurs in many other hills in this district. Usually a rather coarse-grained granite, containing white or red felspar, quartz and hornblende, but no mica. Intrusive into the Malani volcanic series subsequent to the intrusion into it of dykes of diorite.

All these again are distinct from the granite which occurs in dykes and veins among the Aravalli rocks of the main range to the east,[1] and which is characterised by the presence of tourmaline. This type of granite has not been met with west of the main range.

The rocks of the Malani Volcanic Series occurring in the area surveyed this season are generally similar to those described in Mr. LaTouche's progress report for last year, consisting of porphyritic devitrified rhyolites with occasional bands of ash, tuff and pebble beds.

[1] Hacket, Records, G. S. I., Vol. XIV, Pt. 4, p. 282.

All the rocks met with are of either igneous or metamorphic origin, and no trace of any fossiliferous rock has yet been discovered in this region. Consequently it is impossible to refer the formations met with to any definite geological horizon. All that can be said is that they are older than the sandstones which rest unconformably upon the Malanis at Jodhpur, which probably belong to the Vindhyan period.

Some progress has been made with a microscopic examination of the characters of the Malani lavas and allied rocks. So far the microscopic study entirely confirms Mr. Blanford's conjecture, arrived at from an examination of the rocks in the field,[1] that they were originally glassy lavas, which were poured out at the surface.

5. Central India.

South Rewa.
E. Vredenburg.

The work in South Rewah, which had been carried on under Mr. Oldham's superintendence during the previous season, was continued single handed by Mr. Vredenburg during 1896 to 1897 and may be practically considered as finished for the time. The progress reports sent are in the form of more or less disjointed descriptions of the different areas passed over and with the series of specimens collected will greatly assist the compilation of the final report on the Geology of Rewah, which will have to be written by Mr. Oldham. The results of the season's work are more or less of local interest only.

Bhopal.

At the beginning of the last cold season Mr. Vredenburg was posted to Bhopal and Gwalior, and he has not yet returned to head-quarters.

He reports as follows :—

The region so far examined in Bhopal lies between the parallels 22° 30′ and 23° 30′ of latitude, and 77° 30′ and 78° 30′ of longitude. The rocks exposed throughout this area belong to two of the principal geological systems of India, the Vindhyans and the basalt flows of the Deccan and Malwa trap, with their associated intertrappeans. Along the southern portion of the district surveyed, both series are much concealed beneath the post-tertiary Narbada alluvium.

The basalt occurs in more or less discontinuous patches, there being seldom any considerable interval entirely free from that rock; in many cases there remains but a sheet of small thickness occupying the floor of the Vindhyan valleys, while in other instances denudation has not proceeded so far and there are several hundred feet of accumulated lava flows rising into a plateau above which the highest portions of the ancient Vindhyan scarps form small inliers.

[1] Records, G. S. I., Vol. X, Pt. I, p. 17.

It is evident, from the disposition of the geological boundaries, that the modern topography of the Vindhyans reproduces in its main lines the pre-trappean features, the ancient land surface being once more brought to light owing to the comparatively rapid disintegration of the basic volcanic rocks. Remains of a pre-trappean soil and talus exist in several localities, sometimes more or less altered by the contact of the molten lava "intertrappean" beds both calcareous and siliceous are met with, sometimes limited on one side by the Vindhyan slopes whose drainage interrupted by a lava flow gave rise to the lakes in which these rocks were laid down.

The proximity of the great masses of lava has produced no appreciable alteration in the Vindhyans. The most careful search has failed to detect any intrusive dykes or other signs of the immediate neighbourhood of volcanic centres; these must have been situated along some other region, probably further south.

The strata have suffered no disturbance since the basalts were erupted, for these rest horizontally upon the folded Vindhyans and are quite unaffected by a considerable fault which runs through the older rocks in the neighbourhood of Bari (Lat. 23° 2', Long. 78° 7').

Throughout the districts examined, the "black soil" forming the superficial covering over a large portion of the country, is strictly confined to the volcanic outcrops, beyond which it never extends but for very short distances. "Laterite" is found capping some of the higher summits of the basalt plateau.

The Vindhyan rocks exposed belong all to the upper series; although the lowermost member of this division, the lower Kaimur is seen in several localities, yet the underlying rock is in all cases concealed by basalt or alluvium, so that nothing can be said regarding the existence or otherwise of the lower Vindhyans.

The examination of the upper Vindhyans has resulted in thoroughly confirming Mr. Mallet's prevision as to the presence of the Kaimur stage (Mem. Vol. VII, pp. 54, 55, 67, 77, 96). Only a fraction of this area had been previously examined in a cursory manner, and on that occasion the shale bands which constitute the main clue to the interpretation of these unfossiliferous rocks remained generally undetected, concealed as they are in many instances under newer deposits, or else entirely hidden for great distances by the talus of debris from the overlying sandstones. Hence it was concluded that the entire series consisted of one uninterrupted mass of sandstone which it was difficult to correlate with the divisions previously established elsewhere. During the present season, owing largely to the admirably accurate topography of the maps now available, it has been possible to recognise and follow successfully no less than four distinct shale bands, and judging from previously published descriptions there seems to be every

reason for identifying them with the various shales recognised in the Vindhyan regions surveyed to the north and east.

The divisions made out are, in ascending order, as follows:—

(1) Shales, mainly arenaceous and micaceous; a thickness of 200 ft. is seen in places, but the base is nowhere exposed.

(2) Conglomerate with pebbles frequently two or three inches in diameter, consisting of vein quartz and various Bijawar rocks.

(3) Fine grained, very thick-bedded sandstone, an excellent building material very similar to the Chunar sandstone, except that it is uniformly of a dark red colour. The uppermost beds of this division are flaggy. The aggregate thickness of (2) and (3) is about 400 ft.

(4) Compact sandstone, the upper part extremely thick-bedded and forming precipitous cliffs. Thickness 500 ft.

(5) Shales averaging 200 ft. in thickness, resting with a sharp junction on (4) but passing gradually upwards into.

(6) Alternately thick and thin-bedded sandstones forming a succession of scarps which vary greatly in number and size; at the base of this division there exists a remarkably constant band of false bedded flags, largely quarried all along their outcrop. Thickness 400 to 600 ft.

(7) Shales which increase considerably in thickness from east to west. It is this band which is exposed at Ganurgarh fort, this name having been applied to designate one of the Bhander sub-divisions. At the above locality they contain an important limestone which is however only local. Eight miles east of Ganurgarh, the limestone is represented merely by strings of calcite running through the shales, and still further east, the shales themselves thin out almost entirely. At Ganurgarh the shales with the included limestone are over 500 ft. thick, twenty miles east their thickness is reduced to 200 ft., and in the neighbourhood of Bari, about forty-five miles from Ganurgarh, there are not more than 40 ft. of shale largely interbedded with sandstone, while in one locality near Mahilpur (Lat. 23° 16′, Long. 78°5′) the band seems to be altogether extinct.

(8) Sandstone, 800ft. thick. The bedding and petrology vary greatly, the beds generally becoming finer-grained and thinner-bedded in proportion as the thickness of the underlying shales increases. Where the sub-stage (7) attains its maximum dimensions, there is even a subordinate shale band, 60 ft. thick, situated some 120 ft. above the base of (8).

(9) Shales, 200 to 300 ft., argillaceous, brittle, very thin-bedded.

(10) Dark red sandstones very thick-bedded, generally containing fine building stones.

The divisions (1) to (4) agree entirely in their petrology and stratigraphy with the Kaimur rocks of Bundelkhand and of the Son valley; it may be safely concluded that (1) represents the lower Kaimur shales, (2) the Kaimur conglomerate, (3) and (4) the upper Kaimur. The two next divisions (5) and (6) evidently belong to the Rewa stage, and (9) and (10) to the Bhander. The only remaining uncertainty is whether the sandstone (8) should be regarded as the upper Rewa or lower Bhander.

The shales (7) which previous observers examined at Ganurgarh were regarded, principally perhaps on the strength of the limestone, as representing the lower Bhander. But considering their irregular development, and the thickness of the sandstone (8) which is out of all proportion with any recorded observations of the comparatively insignificant lower Bhander sandstone, the simplest explanation would appear to be that (7) represents the Jhiri shales, and (8) the upper Rewa sandstone. It is hoped that this point will be completely settled when the survey is extended as far as the regions previously examined in detail.

The upper Vindhyans are folded along two axes of disturbance, one of them running East-North-East to West-South-West being the continuation of the features developed along the Son and upper Narbada valleys, while the other is nearly at right angles, that is along a North-North-West to South-South-East direction. The combination of these two systems of folds gives rise to outliers of the Bhander stage, and inliers of the rocks underlying the upper Vindhyans, the latter however remaining concealed by the overflowing basalt, so that their nature cannot be ascertained.

6. Central Provinces, Mandla district.

MR. P. N. BOSE.

A large portion of the Central Provinces remains practically unsurveyed, and although several patches of it have been described at different times, much work remains still to be done. Mr. Bose, who was working in the Raipur district before he went on two years' furlough in 1895, was, after rejoining his appointment, sent to the Mandla district north-west of the area already surveyed by him, and has sent in a short progress report, which illustrates the extremely simple structure of that part of the country. Mr. Bose accounts for the limited extent of area surveyed (about 700 square miles) by urging special difficulties

owing to the dense character of the vegetation and unhealthiness of the country. I quote the following from his report:

The area examined lies in the south-eastern portion of the district of Mandla. It comprises the upper portion of the valleys of the Sulkum, the Halon and the Phen which are affluents of larger rivers flowing into the Narbada. The valleys run in directions roughly transverse to the strike of the older rocks, and are separated from each other by hills and uplands formed of the Deccan trap. The general level of the country rises from about 1,600 feet above the sea level in the Sulkum valley to about 2,300 feet in the Phen valley. The higher hills rise from 500 to 900 feet above that level.

Work done during the season 1897 to 1898.

The rocks met with in ascending order are: --

1. The metamorphic rocks.
2. The sub-metamorphic rocks.
3. The lametas.
4. The Deccan trap.
5. Lateritic rocks.

1 and 2. The metamorphic and sub-metamorphic rocks. *Summary and general remarks.*

From the above descriptions it will be seen that there are, in the area examined, three different types of gneiss—(1) massive gneiss in which no bedding is discernible, and which, so far as seen hitherto, is not accompanied by any schists; (2) massive bedded, coarse-grained, hard gneiss associated with highly micaceous gneiss and schists; (3) rather thin-bedded, fine-grained, soft, highly quartzose gneissic or sub-gneissic rock, associated with sub-schistose quartzite and micaceous schist. It is likely that these three types belong to three different ages, the first being the oldest and the last the youngest. The evidence for their separation, however, is not as yet very satisfactory and certainly not conclusive. The third, and presumably the youngest form of gneissic rock mentioned above has a somewhat sub-metamorphic look about it which is emphasized in the immediate vicinity of Motinala by a low dip, not amounting to more than 20°. Moreover, the rock sequence in the Phen section presents no stratigraphical break—at least none that I could discern—between it and rocks of an unquestionably transitional appearance. The question then presents itself—whether the fine-grained quartzose gneissic rock and the phyllites are of the same age? The Sulkum section at Karibah, which shows transitional passage between the phyllites and the gneiss, at least does not show any visible stratigraphic discontinuity between them, would appear to favour an answer in the affirmative. The two sets of rocks may, however, be separated by assuming a fault between them.

3. The lametas.

These rocks are very widespread. Lithologically, they vary between sandstones, which are sometimes pebbly, and siliceous limestones. They rest quite flat upon the denuded

upturned edges of the older rocks, and form a narrow usually interrupted fringe between them and the Deccan trap. Their thickness is very small, not exceeding 30 feet or so; and at places there is just a skin of them.

4. The Deccan trap.

The Deccan trap rests upon the denuded surface of the older rocks and forms all the higher hills and uplands of the area examined.

It is noteworthy that before the Deccan trap flowed on to their surface, the sub-metamorphic and the metamorphic rocks had been denuded away so as to form a slope pretty nearly in the same direction as the present slope of the area, *viz.*, from south to north. For, while in the upper parts of the Phen and the Holon valleys, the older rocks are exposed at a level of about 2,000 feet, in the vicinity of Ghugri even at about 1,600 feet, the ground is covered by the Deccan trap.

5. Laterite.

Lateritic rocks have been met with in small patches in the Phen and the Holon valleys. Economically, they are important as yielding, at places, iron-ore of good quality. Lateritic ore picked up from the bed of a stream near Lalpura in the Phen valley affords means for the maintenance of a sort of intermittent struggle for existence to one primitive furnace. This is the only furnace which I have found within my ground. I have, however, heard of others in the Deccan trap area north-east of it.

7. Sambalpur district and adjoining country.

Mr. F. H. Smith.

During last cold weather season, Mr. Smith was engaged in surveying parts of the Sambalpur district, Sarangarh and Phuljhar with small portions of Bilaspur, Borasamar and Sonpur. The area had been traversed in former years by Mr. V. Ball and others but no connected survey of it had been made, although suspected to contain valuable ore localities, which are probably altogether mythical. Mr. Smith has now sent in a short summary of the results of his survey which is given in the following:—

Crystalline rocks.

The greater part of the Sambalpur and Sonpur districts is occupied by a broad plain of gneiss, with low scattered hills of the same and intrusive rocks. The gneiss is usually syenitic, its chief constituents being white felspar and hornblende. It is frequently coarse-grained and much crushed with lenticular crystals of felspar surrounded by a crushed mass of dark fine-grained hornblendic material. The foliation, which is rare to the westward, but much more developed towards the eastern part of the area, is frequently horizontal or dipping gently; when there is a distinct dip, the general direction of strike varies from N. and S. to N. E. and N. W:

Dykes of dark green, fine and medium-grained diabasic trap are common, with the same general direction as the foliation of the gneiss. And one bold hill—Rossarn—of extremely massive coarse-grained intrusive gabbro or diorite stands up from the gneiss plain.

Siliceous bands and veins also occur in the gneiss. The former are generally of greenish quartz and quartz-mica-schists, but these pass into brecciated and schistose quartzite with occasional bands of jasper, and are in some cases evidently bands of sedimentary rock which have been folded into the gneiss.

West of the Sambalpur plain several patches of massive gneiss occur amongst the sedimentary rocks; they may have formed low hills and islands at the time of the sedimentary deposition.

To the extreme west of the area in the Bilaspur hills there is evidence of great intrusive disturbance. Massive trap-dykes form most of the hills, and strongly foliated chloritic schists with occasional layers of conglomerate, appear to represent metamorphosed sedimentary beds amongst them. Practically the whole of the hill country is composed of sedimentary rocks resting on the surface of the gneiss.

Sedimentary rocks. Older series.

The hills are scarped along their southern and eastern edges, where the beds end off abruptly, overlooking the great gneissic plain. From this they dip away gently westwards and northwards and are overlaid by younger beds, the uppermost of which are found in the Mahanadi valley, which bounds the area to the north.

The hills themselves comprising the Barapahars in Sambalpur, and the Sarangarh and Phuljhar hills are entirely composed of a great series of alternate quartzites and shales, which attains a thickness of over 6,000 feet. The quartzites pass locally into sandstones, grits and conglomerates while the shales are in some cases siliceous slates.

Younger series.

This series is overlaid with slight but distinct unconformity, by another, mainly composed of purple shales, calcareous, siliceous or sandy, and limestones, which forms a flat trough of rocks, some 2,000 feet in thickness along the Mahanadi valley. Both series appear to be totally unfossiliferous, as far as I have been able to discover.

Mr. Ball, who made a rapid traverse over an enormous extent of this country, has referred the whole of these rocks to the Vindhyan system, in his paper on the "Geology of the Mahanadi Basin." But on closer examination, the superposition of a well-defined series of limestones and purple shales over another series, entirely composed of quartzites and shaley slates, points strongly to their much closer connection with the Karnuls and Cuddapahs, and as such I shall regard them.

The best developed section of the lower "Cuddapah" series is found in the Barapahar hills, where the following beds are seen, given in descending order, with their maximum thicknesses :—

Lower beds—Cuddapahs.

1. White granular quartzite	200	feet.
2. Pink and buff shaley limestone and shales	900	„
3. White and pink coarse granular quartzite	400	„
4. Grey and yellow siliceous shales	600	„
5. Compact grey and purplish fine quartzite	400	„
6. Grey and pinkish laminated shales	1,200	„
7. Massive and fine bedded compact quartzite with thin partings of grey shale	2,000	„
8. Purple and yellow slaty shales	400	„
9. Porcellanic shales and green felspathic grit with conglomerate bands	400	„
	6,500	

In this section the sequence seems to be conformable throughout, but westwards the overlap of several members causes unconformities in point of time, although the parallelism of the strata remains perfect. Beds Nos. 1 and 2 thin out E. and W. in the Barapahars, and it is possible that, from the calcareous character of No. 2, they belong rather to the upper Karnul series.

Nos. 3, 4, 5 and 6 are very constant throughout the whole of the hill country. The 7 and 8 bands thin out suddenly to the west of the Barapahars, but re-appear 15 miles to the west in a modified form. To the south-west in Phuljhar all the lower bands appear to be changed, and fine clay shales cover the Phuljhar plain. But this area has not yet been worked out. The No. 9 band is interesting. It occurs constantly, resting on the lower levels of the gneiss, from which it was directly derived, and with which it seems to be more closely connected than with the various beds which overlie it. It is composed of coarse felspathic grit, usually pale-green in colour, with frequent bands of sub-angular pebbles of white quartz. Pale-green porcellanic shales frequently overlie the grit. Bands of this rock are found here and there folded into the gneiss of the Sambalpur plain, and highly metamorphosed, so it is not improbable that it may represent a separate series, and correspond with the 'transitions.'

The general lie of the Cuddapah rocks is with gentle dips to the north, under the Mahanadi valley; but there are several considerable folds in them, resulting locally in faults, with a very constant N. and S. axis. The eastern boundary of the Barapahars is also an extremely disturbed one, the whole series being crushed against the gneiss, with a faulted junction.

Upper beds—Karnul series.

The upper 'Karnul' series of limestones and purple shales overlies the Cuddapahs with slight unconformity. The stratification of the two is however parallel, and the Karnuls have shared in all the disturbances and folds which contort the Cuddapahs.

The Karnuls dip down gently northwards, over the Cuddapahs, and cover the whole of the Mahanadi valley plain, where the dip undulates gently. Exposures are rare on the plain, and only disconnected sections are seen in the larger ravines. The best exposures occur along the bed of the Mahanadi, but even there they are not continuous, and it is impossible to make out the detailed sequence of beds. There seems to be considerable lateral variation in constitution also. The topmost beds of the series have probably not been seen, but so far as at present observed, the following represents a rough section in descending order :—

1. White compact limestone	200 feet.
2. Purple shales with grey laminæ	500 ,,
3. Purplish limestone with discoidal concretionary markings .	150 ,,
4. Purple shales with grey-green siliceous laminæ, thin porcellanic shales and jasper	1,200 ,,
5. Black and buff compact limestone with bands of dark shale and some coarse grit	200 ,,
	2,250

Trap.

Several dykes of the compact dark-green trap occur both in the Karnuls and Cuddapahs, but I have found no trace of interbedded trap in either series.

Laterite.

Thin caps of laterite occur all over the plains, overlying all kinds of rocks, and also amongst the hills. The laterite lying on the gneiss appears to be *in situ* and to be derived directly from the rock beneath, into which it passes by insensible gradations.

Iron-ore.

Limestone and iron-ore are the only minerals of economic value I have met with. The Karnul No. 5 limestone is burnt extensively in Sarangarh for lime.

Many villages have their diminutive blast furnaces, but the *lohars* make no use of the lateritic hæmatite, but prefer a soft porous clayey limonite, which appears to be concretionary, and occurs in the lower Cuddapah shales in small quantities.

No diamonds.

I have not met with any diamonds or diamond mines, nor could I get any information of any ancient workings. The industry of washing for diamonds in the Mahanadi at Hirakoond also seems to have entirely died out.

8. Burma.

*G. E. Grimes.**

During the field season of 1896 to 1897 Mr. Grimes was engaged on the survey of parts of the districts of Magwe, Myingyan and Pokoku in upper Burma; the country surveyed

*As this report goes to press, the lamentable information has reached Calcutta that Mr. Grimes succumbed to an attack of cholera at Thayetmyo on the 11th April. Mr. Grimes has shown great zeal in his work and much ability during the 2½ years of his service, and I was looking forward to the time when he would develop into one of our best stratigraphical geologists. He was only 26 years of age when he died.

in detail is that comprising the Yenangyoung and Yenangyat oilfields, but besides this a considerable area to the east, of which there are no satisfactory maps, was explored.

The country consists of open plains from which a series of low ranges of hills rise, each being composed of and caused by an anticlinal fold, in the larger of which the miocene beds are exposed. These run roughly parallel with each other in a WNW—ESE direction, but are independent. The two largest and most important of these are the Yenangyat and Yenangyoung anticlines, both of which were examined in detail. The other lesser ones are those which form the Pagan and the Gwegyo hills, lie in the unsurveyed country to the east and were only cursorily examined.

The rocks exposed are everywhere the same as those described by Dr. Nœtling in his mémoir on the occurrence of petroleum in Burma, and the only addition to be made to his description is the existence of an unconformity between the upper miocene (Yenangyoung stage) and the pliocene (Irrawadi river) beds which overlie them.

The most important economic results of the survey have been the mapping of the extension of the Yenangyat oilfield and the discovery of what are likely to be two new oilfields on the same anticline. The probable extent of the area over which petroleum may reasonably be expected to be workable is found to be some $6\frac{1}{2}$ miles, or three miles to the south and $3\frac{1}{2}$ miles to the north of Yenangyat. From the nature of the data and reasoning on which this estimate is based, it is more likely to be a minimum than a maximum. Besides this extension of the Yenangyat field, Mr. Grimes found another place where the axis of the anticline rises, and in block 58 N of the Yenangyoung oilfields survey there is a small exposure of the lower miocene (Prome stage); it is very probable that an oilfield, small perhaps but workable, will be found here.

To the north of Yenangyat a larger exposure of the beds of the Prome stage was found and here the first or uppermost oilsand is freely exposed at the surface; Mr. Grimes was informed by the villagers that the hill had been on fire last year where this oilsand is exposed and that it had burnt for several months with flames three feet high. The ground was blackened and showed signs of burning, so this statement may well be correct. It is probable that there is a larger and more prolific oilfield here than that of Yenangyat and not impossibly than Yenangyoung. The southern end of this may be placed in block B of the Yenangyat oilfields survey and the northern some 6 miles north of the limit of the survey.

In the Yenangyoung oilfield the exposure of miocene beds was found to widen out to the south of Dr. Nœtling's survey representing a slight rise of the axis of the anticline in blocks 33 and 45 and then to close in and finally disappear. It is possible that a boring put down here would strike oil, but the field would be a small one and probably not very productive.

In the Pagan and Gwegyo anticlines the lower miocene—petroliferous—beds are not exposed. In the Gwegyo hills some places were pointed out where if was said that oil had been seen at times. It is possible that in the future petroleum will be worked at both these localities, but the fact that both anticlines are faulted, conjoined with the absence of visible oil-springs, is not promising for a large supply of petroleum.

On his return from the field Mr. Grimes visited Akyab and examined the neighbourhood with a special view to the possibility of sinking an artesian well, the water-supply of the town being both scanty and inadequate. The town is built on recent deposits, and the only exposures of rock in the neighbourhood are along the crest of an anticlinal, apparently the continuation of that which forms the Baronga island. In these circumstances it would be hopeless to look for a water supply from the tertiary rocks even if they could be reached, while neither the nature nor the disposition of the recent deposits is such as to lead to any anticipation of an artesian well of the deltaic type being met with.

Season 1897 to 1898.

Mr. Grimes was principally engaged during the last camping season in surveying the Kabwet coal field in detail, after which he proceeded to examine several smaller areas near Mandalay. He has sent in the following short reports :—

The Kabwet Coal field.—During the first two and-a-half months of the present (1897-98) camping season I was engaged in the examination of the Kabwet coalfield and the surrounding area between Kabwet and Male in the District of Shwebo, Upper Burma.

Description of rocks.

The rocks in this area are chiefly sandstones mostly soft and current bedded but sometimes calcareous in which case they are very hard. Almost everywhere the sandstones contain numerous rounded hard calcareous concretions, which weather along the original planes of bedding. Interstratified with the sandstones are some strings and thin beds of greyish or bluish shale which are quite subordinate to the sandstones and nowhere of any great thickness, and besides these there are at separate horizons a bed of contemporaneous basaltic lava, a bed of carbonaceous shale and coal and a thick mass of limestone.

Although all the sandstones have many characters in common and those in different parts of the area and at different horizons are often very difficult to distinguish from one another, besides recent alluvial beds four stages may be distinguished in the sandstones which can be identified and mapped with a fair degree of accuracy, and the following is a description of them and of the alluvial beds in descending order.

Recent deposits.

The alluvial beds, which are chiefly deposited in a narrow strip of country running from north to south across the area, consist chiefly of ordinary river sands with beds of mud and clay in places. Small calcareous concretions resembling kankar

are found in them in places but they are not widely distributed in the beds.

Of recent origin also are the greater part of the fragments of silicified wood which are everywhere thickly scattered over the surface of the ground in the area examined. This is called by the Burmans "ingyin kyauk" and they say that the fragments are pieces of the ingyin tree (the acacia ferruginea) which have been left lying on the ground and there silicified. In support of this local theory of the origin of the wood I have on several occasions noticed marks on the wood as if it had been cut by a "dah" and besides this there is the universal distribution of the silicified wood, mostly in angular fragments in every part of the area where the "ingyin" tree grows. All the silicified wood, however, is not of recent origin as will be shown later.

Tertiary beds.

1st Stage.—(The uppermost) strata of the tertiary strata consist chiefly of yellowish and yellowish white current—bedded sandstones which are so soft as easily to crumble between the fingers. These contain small irregularly shaped calcareous concretions and usually have a network of calcareous strings and besides these, there are larger rounded calcareous concretions and layers of hard calcareous sandstone. With these sandstone beds there are often interstratified thin bands of greyish and bluish-grey shales and sandy shales, but these are quite subordinate and never of any great thickness. Conglomerate beds are found but are comparatively rare. Embedded in the sandstones and evidently of the same age there are pieces of siliceous fossil wood, like that which I have seen in other parts, and of this large tree trunks are to be seen in places. Lying in one of the stream beds, where it crosses the sandstones near the base of this stage there was a very large, rounded and polished boulder of granite, quite unlike any of the rocks which I know to occur in the surrounding country so that it must have come from a considerable distance, and as it is much too large to have been transported to its present position by any of the physical agencies, now at work, I concluded that it had come out of the beds on the top of which it is now resting.

2nd Stage.—The beds of the 1st stage pass conformably down into those of the 2nd stage, which consist chiefly of fairly soft yellowish, reddish-yellow and brownish sandstones mostly somewhat micaceous. They are as a rule somewhat harder than the beds of the 1st stage and more regularly bedded, and they also contain very numerous and often large greyish calcareous concretions, which are harder than those in the beds above, and besides these there are several thick layers of very hard calcareous sandstone, which latter is mostly conglomeratic. Interstratified with the sandstones are quite subsidiary bands of greyish and bluish-grey shale, mostly somewhat sandy and very similar to that of the 1st stage.

3rd Stage.—The beds of this stage also are almost entirely composed of sandstones, which vary, however, somewhat in appearance in the different

parts of this stage. The upper sandstones are white, bluish-white or yellow in colour and are usually very coarse and friable, whilst those in the lower part are greyish and yellowish and harder. Calcareous concretions and bands are present but are not so common as in the beds higher up and they are also chiefly confined to the lower beds of this stage. With the sandstones there are a few beds of soft shale and clay of blue or bluish-grey colour and the bed which lies just underneath the coal, in the southern part of the area is of a particularly bright blue colour. At one horizon in these beds and resting directly upon sandstone there is a bed of basic lava which is thickest and most prominent at Nat-taung, but it decreases in thickness as one gets away from that centre and gradually dies out. Lying on the top of the lava are indurated red-clays, which likewise die out to the north and east but extend to a short distance beyond the limits of the lava. At a horizon a little above the lava and red-clay there is a bed of carbonaceous shale or coal which extends over the whole of the area where the beds of this age are exposed and so much beyond the lava and red-clay. This bed varies very considerably in composition and thickness within a short distance, and it is doubtful if it is perfectly continuous over the whole area, as in one or two places where the beds of this horizon are fairly well exposed, I failed to find any traces of it; the exposures of it, however, are few in number, owing to the beds being for long distances overlaid by recent deposits and to the way in which the country was covered up at the time of my visit by jungle with long grass. With regard to the composition of this bed I can only now say, before the analysis of my samples, that judging from the appearance of the beds, the most westerly exposures between Letkokbin and Kabwet are the richest in carbon, and all the other exposures show an inferior coal or even only a brown carbonaceous shale with streaks of coal. Embedded in this carbonaceous shale and coal are numerous small pieces of amber.

4th Stage.—The beds of this stage consist also chiefly of massive greyish, whitish and yellowish sandstones, mostly coarse but sometimes fine-grained and in places argillaceous. Hard calcareous concretions and bands are common in them and the uppermost beds have a considerable resemblance to the sandstones of the 3rd stage. Interbedded with these sandstones are some brown shales which are typical of this stage and quite unlike the shales in the other stages. In the northern part of the area there is interstratified with these beds a thick mass of blue limestone which passes gradually into calcareous shale and so into the other beds of the series. This limestone is apparently unfossiliferous, as although I searched in it carefully, I could not find signs of a single fossil. Running through these rocks there are numerous dykes of dolerite which resembles in appearance the basic lava interstratified with the beds of the 3rd stage, but here it is evidently intrusive, as in several places it is to be seen breaking through and running across the bedding planes of the sandstones.

Coming now to the structure of the country, we find that the rocks are bent into a number of synclinal and anticlinal folds whose axes have an approximately north and south direction, and besides smaller faults the area is traversed from one end to the other by two large faults also running approximately north and south.

Structure.

The beds of the 1st and 2nd stages which are exposed in the western patr of the area and bounded on the east by the more westerly of these two faults, are folded with generally quite low dip. The beds of the third stage lie between the two great faults mentioned above, and as the latter tend to converge towards the north, the area of these beds is narrower in the northern than in the southern part of the country examined. In the northern part of the area these beds are bent into a single anticlinal arch which sinks towards the north so that only beds younger than the coal are exposed to the north of the Khodaung Choung; but in the southern part where the breadth of the exposure of the beds of the third stage is greater, there are more foldings and the coal is worked in a small synclinal basin between Lethokbin and Kyetsubin which is bounded by the western fault. The greater part of the area between the faults is, however, covered up by recent deposits so that the folding of the beds beneath cannot always be seen.

The beds of the fourth stage, which are exposed in a narrow strip of country running along the Irrawadi and bounded to the west by the eastern-most of the big faults, are everywhere steeply inclined and their dip is mostly vertical or almost so and when it is lower this is generally seen to be due to local contortions.

Of the exact age of these sandstone beds there is no direct evidence in the area examined, and one has to rely almost entirely on their lithological resemblance to beds of known age in other places. The beds of the first stage are in many respects like the pliocene sandstones, which I have examined in the Myingyan and Pokokku districts and like them they are current bedded soft sandstones containing silicified fossil-wood, so that I am inclined to think that the beds of the first stage are possibly of pliocene age also. The beds of the first stage rest quite conformably on those of the second stage, and I have sometimes doubted whether the latter ought to be separated from the first stage as they are in many respects alike, and besides the beds of the second stage are very unlike the upper miocene sandstones and gypsum bearing shales which underlie the pliocene farther south.

Age of sandstones.

The beds of the third stage and those of the second stage are here separated by a fault, so that the relationship between them cannot be seen, but I think that the former are older than the latter, as they (the beds of 3rd stage) in many ways resemble the miocene beds of other places and are entirely unlike any post pliocene beds I have seen in Burma.

The beds of the fourth stage are also separated from those of the third stage by a fault, but it is probable that this fault does not extend quite to the south of the area, and if not, the beds of the third stage are there resting on those of the fourth stage. Besides this, however, we have further evidence tending to show that the beds of the fourth stage are older than those of the third stage, in the fact that they are pierced by intrusive dykes of dolerite, which is exactly like that forming the bed of lava, which is interstratified with the beds of the third stage.

During the latter half of this present camping season (1897-98) I have been examining those parts of the Mandalay and Sagaing Districts which are mapped on sheets Nos. 260 and 261 (1″-1 mile) of the Upper Burma Survey. This area is divided by the river Irrawadi into two very unequal parts, the physical features of which are quite unlike, the larger and eastern part being the Mandalay plain and the smaller and western area the Sagaing hills. As I shall want to refer to the Sagaing hills when considering the rocks of the hills in the other area, I shall consider them first although they were not examined till last.

Sagaing hills.—The rocks in these hills consist chiefly of a series of crystalline limestones, quartzites and mica schists and resting unconformably on them coarse current bedded sandstones probably of pliocene age.

Crystalline rocks.

The first series, that of the metamorphic rocks, forms the main mass of the hills and all the highest ridges are formed of them. The limestones of this series vary very considerably in the different parts of the hills and in the different beds, in the southern part of the hills they usually contain a lot of mica and other minerals included in them, whilst farther north near Mingun and Tonbo we find hills composed of an almost pure white crystalline limestone and these are the highest ridges in the range of hills. If we trace these limestones, however, along their strike to the north-west we find in the low hills on the west side of the range, blue limestones which are not crystalline and which are in appearance very like the limestones in the Shan hills to the east of Mandalay.

Interstratified with the limestones but usually in very thick beds are quartz and mica schists, in which rocks the mica is often concentrated in definite layers so that the rock consists of alternate layers of quartzite and mica schist; in other places, however, where the rocks contain more mica the whole is a mica schist. On the western side of the hills in the same relation to these quartzites and mica schists, as the blue limestone is to the crystalline limestone, we find coarse dark reddish brown ferruginous and often micaceous sandstones. [1]

[1] In a note which Mr. Grimes sent a few days before his death, he announces the fact that this sandstone has yielded plant remains. This is an important discovery, and it is to be hoped that more details may be forthcoming when his diaries and collections reach Calcutta.

Of the age of these rocks there is no definite evidence, and the only indication we have is the likeness of the blue limestone to that in the Shan Hills east of Mandalay, which Dr. Nœtling on the evidence of some fossils obtained by him, regards as lower silurian or even older.

Age of rocks.

Resting unconformably on the upturned edges of these older and metamorphosed rocks a series of soft white, yellowish-white and brown current bedded soft sandstones, mostly pebbly and especially in the northern part of the hills often conglomeratic In these are dark reddish brown ferruginous strings and layers and rounded calcareous concretions. These beds are exactly like the pliocene beds in the Myingyan district and perhaps two specimens of fossil teeth which I have obtained from these beds may enable the question of their age to be definitely settled.

Tertiary rocks.

The older metamorphosed rocks, the plains of foliation of which correspond with the original planes of bedding, have in the southern part of the hills everywhere a steep dip, but at the northern end of the range this decreases somewhat. The dip is everywhere to the east with the exception of the eastern side of the southern end of the hills where it is a steep westerly one.

Structure.

The newer, probably pliocene, beds rest on the upturned edges of the older beds and are also dipping to the east, but with low angles under 20°. These beds are chiefly exposed on the eastern side of the hills, starting from near Wachet and extending towards the north, at first their exposures are not very elevated above the Irrawadi, but as one goes north one sees them forming higher and higher hills and extending farther and farther west, until at the northern end of the range they have completely covered up the older beds and the hills are formed by them alone. This area consists of a large flat plain, extending for many miles around Mandalay out of which a number of isolated hills arise and the rocks may be divided into two series, the one consisting of the metamorphosed and crystalline rocks of the isolated hills and the other the alluvial beds of the plain.

Mandalay plain.

The rocks composing the hills vary very greatly in character, so that almost every hill is composed of a different rock, but they are all highly metamorphosed and mostly crystalline. The chief rocks are crystalline limestone and quartzite, the first forming the hills near to and to the east of Mandalay, and the latter being most prominent in those farther north. Mandalay hill is composed of a white crystalline limestone containing mica and other minerals, but at Yangintaung which is nearer the Shan hills the limestone is greyish and not so highly metamorphosed and it is much more like the rocks exposed on the western

Description of rocks.

slopes of these hills. Five miles to the north, however, in the group of hills south-east of Lundaung, we meet with entirely different kinds of rock and here Gondama Taung and the hills to the south of it are composed almost entirely of quartzite, which is however, mostly somewhat micaceous and calcareous, but Shwe Voung Daung to the west of these is formed chiefly of mica schists, with which are associated some crystalline rocks. Only a mile to the east of Gondama Taung, the beds of which are dipping to the east, in the low hills on the north side of Kangyi village, we find an exposure of coarse granite and at Sagadaung about two miles to the north of Gondama Taung we have greyish white gneiss. The other hills, which I have examined to the north and east of these are all composed of quartzites and micaceous schists.

Owing to the isolated nature of the exposure of these rocks and also to the fact that definite dips and strikes cannot always be seen in them, it is impossible from an examination of these hills alone to determine the relation of the different rocks to one another, and in order to ascertain this certainly it will be necessary first to examine the hill country around. The rocks in the isolated hills are apparently outliers of those in the Shan hills as an examination of the western slopes of those hills at different places showed similar rocks to those in the isolated hills, especially to those close to them. In some cases, however, as for instance Mandalay hill, the rocks of the hills in the plain are quite different from any I have seen in the Shan hills, but in these cases they show crystalline structure highly developed, and the difference is most probably due to the metamorphic changes which have evidently taken place in them. The white crystalline limestone of Mandalay hill is certainly very unlike the blue limestone of the hills to the east, but a similar difference and change can be seen in the Sagaing hills, when the limestone is traced along its strike from one side of the hills to the other, so that in this case too the difference is probably due to metamorphism.

The granite and possibly the gneiss are in all probability intrusive, but whether the other rocks all belong to one system is still an open question. In the Sagaing hills we see similar rocks interstratified with one another, but an examination of the Shan hills between Tonbo and Maymyo showed practically nothing but limestone, and until the relation of this limestone to the quartzitic and schistose rocks of the same hills farther north is established, the stratigraphical connection between the outliers of these rocks cannot be determined.

The whole of the plain from which these isolated hills rise is covered by alluvial beds, which present an uniformly flat surface, so that but little can be seen of them. On the top, especially in the eastern part of the plain they seem to consist chiefly of mud, silt and fine grained sand and deeper down the wells show coarser sand, but where the Irrawadi crosses the plain the sections shewn in the banks of the river are all coarse sand.

9. North-West Frontier.

Mr. H. H. Hayden.

The military operations across the Afridi border of the North-Western Frontier under the Command of General Sir W. S. A. Lockhart, K.C.B., K.C.S.I., offered an opportunity of adding to our knowledge of the geological structure of that country. In October 1897, Mr. Hayden received permission to accompany the Tirah Expeditionary Force and was absent on that duty till January 3rd, 1898. At various times I have traversed parts of the country myself, so for instance when accompanying the Miranzai field force in 1890 to 1891, and during several trips through the Khaibar and Kabul valleys. Some of the results are embodied in my paper on the Safed Koh, published in the Records, Vol. XXV, pp. 59, ff., but the information gained was necessarily sketchy and in parts speculative, but it is satisfactory even to find that Mr. Hayden's work last season has resulted in establishing the truth of one supposition, namely, that palæozoic and triassic rocks make their appearance along a great east to west dislocation, which separates the main mass of the Safed Koh range from the "outer" hills lying south of it.

The following is a brief summary of the results of Mr. Hayden's work :—

Structure of country.

The country between the Samana range and the Khaibar consists of a series of parallel mountain-ranges, running east to west. The rocks, which are chiefly of mesozoic age are folded into numerous anticlines and synclines with many inverted folds and faults. South of the Bara valley no rocks older than mesozoic are found, but along the southern flank of the Surghar range these beds are faulted against strata of palæozoic age.

Rocks represented.

The following is a broad sub-division of the rocks in descending order :—

10. Light-coloured limestone with nummulites (Kohat, Ustarzai, Hangu, etc.)	Upper eocene.
9. Green and red shales and sandstones (Kai and Waran Valley.)	Lower eocene.
7. Grey limestones, with sandstones . . . . . and 8. Shaley limestones and subordinate shales . . .	cretaceous and jurassic.
6. Massive coral limestone (Gorge between Bagh and Dwatowi)	rhaetic.
5. Red gritty shales, grits, conglomerates and reddish-brown needle shales (Bara and Bazar valleys).	trias.
4. Limestone and calcareous sandstone, with middle Productus limestone fossils.	permian.
3. Greenish-brown shales, with flaggy quartzites and subordinate limestone bands (Chura and Khaibar).	permo-carbon-ferous.
2. Altered limestones of Rohtas hill, Ghund Ghar and Surghas range.	carboni-ferous.

1. Hard slates and white quartzites of Surghar range (near Sher Khel in Bara valley.) } order palæozoic.

Fossils.

Owing to paucity of fossils much of the above classification is merely tentative, but eocene fossils were found in Maidan and cenomanian brachiopods in the Waran valley, while between Chura and the Bazar valley are beds containing species found in the middle productus limestone of the Salt range.

Igneous rocks.

No igneous rocks are found *in situ* south of the Surghar range, but they probably occur a little further west on the southern flanks of the Safed Koh. In the Khaibar a decomposed dolerite is found among the carboniferous rocks, and in the stream-beds many boulders of altered gabbro.

Appendix I.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India, from the 1st January 1897 to the 31st March 1898.

ADELAIDE.—Geological Survey of South Australia.
" Royal Society of South Australia.
ALBANY.—New York State Museum.
BALTIMORE.—Johns Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Kon. Natuurkundige Vereeniging in Ned.-Indie.
BERKELEY.—University of California.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
" K. Preuss. Akad. der Wissenschaften.
" K. Preuss. Geologische Landesanstalt.
BOLOGNA.—R. Accad. delle Scienze dell' Istituto di Bologna.
BOMBAY.—Natural History Society.
" Royal Asiatic Society.
BORDEAUX.—Sociéte Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterlandische Cultur.
BRISBANE.—Queensland Branch of the Roy. Geog. Soc. of Australasia.
" Queensland Museum.
" Royal Society of Queensland.
BRISTOL.—Naturalists' Society.
BRUSSELS.—Société Royale Belge de Geographie.
BUCHAREST.—Museului de Geologia si de Paleontologia.
" Geological Bureau.
BUDAPEST.—Kön. Ungarische Geologische Anstalt.
" Ungarische Geologische Gesellschaft.
" National Museum.
BUENOS AIRES.—Acad. Nacional de Ciencias.
" Museo Nacional.
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
" Asiatic Society of Bengal.
" Calcutta University.
" Editor, Indian and Eastern Engineer.
CAMBRIDGE.—Philosophical Society.
" University of Cambridge.
" Woodwardian Museum.

Cambridge, Mass.—Museum of Comparative Zoölogy.
Canada.—Hamilton Association.
Cape Town.—South African Geological Commission.
Cassel.—Vereins für Naturkunde.
Christiana.—The Committee, Norwegian North-Atlantic Expedition.
Cincinnati.—Society of Natural History.
Copenhagen.—Kong. Danske Videnskabernes Selskab.
" Academie Royale des Sciences et des Lettres.
Des Moines.—Iowa Geological Survey.
Dijon.—Academie des Sciences et Belles-Lettres.
Dresden.—K. Min. Geol. und Præhistorische Museum.
" Naturwissenschaftliche Gesells. Isis.
Dublin.—Royal Dublin Society.
" " Irish Academy.
Edinburgh.—Royal Scottish Geographical Society.
" " " Society of Arts.
Geneva.—Societe de Physique et d'Histoire Naturelle.
Glasgow.—Glasgow University.
" Philosophical Society.
Gotha.—Editor, Petermann's Geog. Mittheilungen.
Göttingen.—K. Gesells. der Wissenschaften.
Halifax.—Nova Scotian Institute of Science.
Halle.—Academia Cæsarea Leop. Carol. Nat. Curiosorum.
Helsingfors.—Société de Geographie de Finlande.
Königsberg.—Physikalische Ökonomische Gesellschaft.
La Plata.—Museo de La Plata.
Lausanne.—Société Vaudoise des Sciences Naturelles.
Lawrence.—Kansas Geological Survey.
" " University.
Leeds.—Yorkshire College.
Leide.—Ecole Polytechnique de Delft.
Leipzig.—Kön. Säch. Gesells. der Wissenschaften.
" Vereins für Erdkunde.
Liège.—Société Geol. de Belgique.
Lille.—Société Geol. du Nord.
Lisbon.—Section des Travaux Geol. du Portugal.
Liverpool.—Geological Society.
" Literary and Philosophical Society.
London.—British Museum (Natural History).
" Geological Society.
" Geological Survey of the United Kingdom.
" Iron and Steel Institute.
" Linnean Society of London.
" Royal Geographical Society.
" " Institution of Great Britain.
" " Society.
" Society of Arts.

LONDON.—Zoölogical Society.
MADRID.—Real Academia de Ciencias Exactas Fisicas y Naturales.
,, Sociedad Geographica de Madrid.
MAINE.—Portland Society of Natural History.
MANCHESTER.—Geological Society.
,, Literary and Philosophical Society.
MARSEILLES.—Faculty des Sciences.
MELBOURNE.—Australasian Institute of Mining Engineers.
,, Dept. of Mines and Water Supply, Victoria.
,, Royal Society of Victoria.
MEXICO.—Instituto Geologico de Mexico.
MILAN.—Sociéta Italiana di Scienze Naturali.
MINNEAPOLIS.—Minnesota Academy of Natural Sciences.
MOSCOW.—Société Imp. des Naturalistes.
MUNICH.—Kon. Bayerische Akad. der Wissens.
NAPLES.—Reale Acad. delle Scienze Fisiche e Matematiche.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, American Journal of Science.
NEW YORK.—Academy of Science.
,, Geological Survey.
OTTAWA.—Geological and Natural History Survey of Canada.
,, Royal Society of Canada.
OXFORD.—University Museum.
PARIS.—Comptoir Geologique de Paris.
,, Department of Mines.
,, Editor, Annuaire Geologique Universel.
,, Ministere des Travaux Publics.
,, Museum d'Histoire Naturelle.
,, Société de Geographie.
,, ,, Geologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PERTH.—Dept. of Mines, Western Australia.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Lincei.
,, Reale Comitato Geologico d'Italia.
,, Societa Geologica Italiana.
SALEM.—American Assoc. for the Advancement of Science.
,, Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SINGAPORE.—Straits Branch of the Royal Asiatic Society.

SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—Kon. Svenska Vetenskaps Akademie.
ST. PETERSBURG.—Academie Imperiale des Sciences.
" Comite Geologique.
" Musée Geol. de l'universite Imperiale.
" Russ. Kaiser. Mineralogische Gesells.
SYDNEY.—Australian Museum.
" Dept. of Mines and Agric., N. S. Wales.
" Geological Survey, " "
" Linnean Society, " "
" Royal " , " "
TOKIO.—Deutsche Gesells. für Natur. und Volkerkunde.
" Imperial University of Japan.
TORONTO.—Canadian Institute.
TURIN.—Osservatorio della R. Universita.
" Reale Accad. delle Scienze.
UPSALA.—Upsala University.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissenschaften.
" K. K. Geog. Gesellschaft.
" K. K. Geol. Reichsanstalt.
" K. K. Naturhistorischen Hofmuseum.
WARSAW.—Inst. Agronomique et Forestier.
WASHINGTON.—Philosophical Society.
" Smithsonian Institution.
" U. S. Dept. of Agriculture.
" " Geological Survey.
" " National Museum.
WELLINGTON.—Geological Survey, New Zealand.
" Mining Dept., "
" New Zealand Institute.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Naturforschende Gesellschaft.

The Governments of Bengal, Bombay, Burma, India, Madras, the North-Western Provinces and Oudh, and the Punjab.

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Appendix II.

The Inspector of Mines in India.

This officer being under my administrative control, I have to report that Mr. James Grundy during the period from the 1st January 1897 to the 31st March 1898, his duties consisted of a large number of inspections of coal and mica mines, which entailed a considerable amount of office work as is shown in the Annual Report of the Inspector of Mines for 1896 which was printed during the autumn of 1897. I returned too late from furlough to enable me to make such alterations in this publication as appeared to me desirable.

Mr. Grundy was absent on privilege leave from the 12th October 1897 to the 13th January 1898.

CALCUTTA;
The 1st April 1898.

C. L. GRIESBACH,
Director, Geological Survey of India.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1898

TO THE 31ST MARCH

1899.

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Museum Assistant.

T. R. Blyth.

Geological Museum, Library, and Office, Calcutta.

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VOL. I. Royal 8vo, pp. 309, 1859 (*out of print*). Pt. 1, 1856 (*price* 1 Re.): Preliminary notice on the Coal and Iron of Talchir.—On the geological structure and relations of the Talchir Coal-field:—Gold-yielding deposits of Upper Assam.—On specimens of gold and gold dust from Shué-gween. Pt. 2, 1858 (*price* 2 Rs.): On the geological structure of a portion of the Khasi Hills.—On the geological structure of the Nilghiri Hills (Madras). Pt. 3, 1859 (*price* 2 Rs.): On the geological structure and physical features of the Districts of Bankura, Midnapore, and Orissa.—On the laterite of Orissa. On some fossil fish-teeth of the genus Ceratodus, from Maledi, south of Nagpur.

VOL. II. Royal 8vo, pp. 341, 1859 (*out of print*). Pt. 1, 1860 (*price* 2 Rs.): On the Vindhyan Rocks, and their associates in Bundelkand. Pt. 2, 1860 (*price* 3 Rs.): On the geological structure of the central portion of the Nerbudda District — On the tertiary and alluvial deposits of the central portion of the Nerbudda Valley.—On the geological relations and probable geological age of the several systems of rocks in Central India and Bengal.

VOL. III. Royal 8vo, pp. 438. Pt. 1, 1863 (*price* 3 Rs.) (*out of print*). On the geological structure and relations of the Raniganj Coal-field.—Additional remarks on the geological relations and probable geological age of the several systems of rocks in Central India and Bengal.—Indian Mineral Statistics, I. Coal. Pt. 2, 1864 (*price* 2 Rs.): On the Sub-Himalayan Ranges between the Ganges and Ravi.

VOL. IV. Royal 8vo, pp. 450. Pt. 1, 1863 (*price* 2 Rs.): Report on the Cretaceous Rocks of Trichinopoly District, Madras. Pt. 2, 1864 (*price* 2 Rs.) (*out of print*):* On the structure of the Districts of Trichinopoly, Salem, &c. Pt. 3, 1865 (*price* 1 Re.): On the Coal of Assam, &c.

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VOL. XVI. Royal 8vo, pp. 264. Pt. 1, 1879 (*price* 1 Re. 8 As.): Geology of Eastern Coast from Lat. 15° to Masulipatam. Pt. 2, 1880 (*price* 1 Re. 8 As.): The Nellore Portion of the Carnatic. Pt. 3, 1880 (*price* 2 Rs.): Coastal Region of the Godávari District.

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GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1898

TO THE 31ST MARCH

1899.

UNDER THE DIRECTION OF

C. L. GRIESBACH, C.I E, F.G.S.

CALCUTTA:

OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA

1899.

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

CONTENTS.

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PART I.—HEAD-QUARTER NOTES.

Director's Tours.

During the twelve months under review, I made the following tours:—

(1) From the 17th May to 22nd June 1898 to Simla to arrange the programme of surveys for the year under review.

(2) From the 3rd to the 30th July 1898 to the Madras Presidency on inspection.

(3) From the 7th October to the 10th November 1898 to the Kumaun Himalayas to re-visit certain sections north-east of Almorah which had been surveyed some years ago by myself and which required revision.

(4) From the 9th to the 31st March 1899 to Rajputana to inspect Mr. LaTouche's surveys.

1. MUSEUM AND LABORATORY.

The Curator, Mr. C. S. Middlemiss, B.A., reports as follows :—

Change of Curators.

"On the 1st November 1898, I took over the curatorship from Dr. T. L. Walker, and the following is a brief report on the work done in the Museum and the Laboratory during the past year.

"The upper north gallery of the Museum was closed to the public during the past year, whilst extensive re-arrangements of the collection were in progress, consequent on the removal of the type-specimens referred to in the last annual report. This work is still in progress.

Museum.

"Of the 84 cases of economic specimens in the mineral and rock gallery, 16 more have now been labelled, leaving 16 still to do.

"The collection of Himalayan triassic fossils received back from Vienna has been numbered with the type-numbers and put away. All other returned types have similarly been disposed of, so that the type-collection is now in complete order.

"Numerous assays and a few complete analyses have been made in the laboratory by Dr. Walker and Mr. Blyth. Considerable difficulty has been felt in carrying out quantitative analyses by the lack of a special room detached from the laboratory itself where quiet, freedom from dust and privacy may be obtained. The difficulty of obtaining chemically pure re-agents from local sources has also been a hindrance in the past; but this will now be remedied, it is hoped, by orders for re-agents having been sent to well-known European firms.

Laboratory.

"Increased accommodation in the Officer's work-room has been obtained by lining the walls with shelves for the reception of collections under examination.

Meteorites.

"The following meteoritic irons have been obtained by exchange from Mr. H. A. Ward of New York:—

Roebourne, Queensland, Australia; found 1894.

Ballinoo, on the tributary of Murchison River, 10 miles south of Ballinoo, West Australia; found 1893.

Smithville, De Kalb Co., Tennessee, United States, America; found 1893.

Mungindi, Queensland, Australia; found 1897.

El Capitan, Bonito, North Mexico; found 1893.

Nocoleche (no details as to history of this meteorite sent).

"A stony meteorite which fell at Gambat (lat. 27°24′ and long. 68°27′) in the Khairpur State, Sind, on the 15th September 1897, has been added to our collection. The fall is reported to have taken place in bright sunshine at 4 P.M. There was a loud report heard, followed by a sharp whizzing sound, and then a thud as it struck the ground, the soil of which it penetrated to a depth of 11 inches at an angle of 50° with the horizon.

Meteorite Fall.

"It was almost completely covered with the usual black crust, being a perfectly whole meteorite. Weight 7,171 grains, specific gravity 3·53, size in inches $8\frac{3}{4} \times 7\frac{1}{2} \times 3\frac{3}{4}$. It has been modelled and portions of it have been disposed of in the usual way.

Donations to the Museum.

The following is a list of donations made to the Museum during the past year :—

Donation.	*Presented by—*
Specimens of blue kyanite rock with emphyllite . .	R. D. Tipping, Pollibetta, Coorg.
Twinned crystal of muscovite	H. G. Parons, Pollibetta, Coorg.
The meteorite that fell in a field at Gambat, Khairpur State, Sind, on the 15th September 1897, weight 7,170·95 grammes.	Col. A. H. Mayhew, Collector of Shikarpur, Sind.
Fossil found in a bed of conglomerate 60 feet thick, near Chab tunnel, half way between Fand and Makhud, 12 miles from the Indus, Rawal Pindi district, formation Siwaliks.	Lieut. H. E. C. Cowie, R.E., Asst. Engineer, Mari-Attock Railway, Langar division, Chab.
Three fossils from the Siwalik Hills, and a specimen of Caunopora placenta in Stromatopora ("Stagshorn") elegans, from the Chinkerwell quarry, by Teignmouth Road, near St. Mary's Church.	W. Theobald.
A crystal of phlogopite, from Wakefield, Quebec Province.	Prof. F. D. Adams, McGill University, Montreal.
One specimen of alluvial gold, from Tolima State, Colombia Republic, S. A. ; one specimen of native gold in quartz, from between Antioquia and Tolima States, Colombia Republic, S.A.; one specimen of alluvial gold from Kahajan River, about 400 miles from sea, South Borneo; and a specimen of galena, from the Celebes.	Arthur FitzGibbon, Sibpur, Howrah.
Several fossils, trilobites, etc. (upper silurian), from the neighbourhood of the Baroghil Pass.	Lieut. I. H. Grant, I. S. C., 29th Punjab Infantry, Gairat, Chitral."

List of Assays and Examinations made in the Laboratory during the past year.

Substance.	For whom.	Result.
Three specimens from the Gwalior State, for determination.	Col. D. G. Pitcher, I.S C., Director of Land Records, Gwalior State, Gwalior.	*1. Sand found in a nullah near the Chamba river.* Garnet sand, with a little rutile and magnetite. *2. Specimens of natural glasing, from a lime-kiln recently opened and supposed to be produced by the fusion of quarts of which there is any quantity in the limestone."* The glaze on the specimens of sandstone is probably due to the presence, in the local soils, of salts of sodium.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance.	For whom.	Result.
		3. "*A piece of granite which seems to contain some metallic substance from another place.* The granite does not contain any metal. In certain positions the light reflected from the cleavage surfaces of minute felspar crystals causes them to resemble specks of a metallic substance.
Eight specimens from Cook and Sons' Quarries at Katni, for determination.	F. H. Cook and Sons' Lime works, Katni, E. I. R.	1. "*Limestone, with streaks of supposed gold, depth 30 feet.* Limestone, with iron pyrites. 2. *Mineral found at a depth of 20 feet.* Highly calcareous clay. 3. *Mineral found at a depth of 20 feet.* Calcareous clay with compact limestone bands. 4 and 5. *Earth from a depth of 10 to 30 feet.* Magnesian clay, coloured by iron compounds. 6. *Mineral found at a depth of 15 feet.* Indurated calcareous clay. 7. *Mineral found at a depth of from 10 to 20 feet along with Nos. 2 and 3.* Calcareous shale with bands of bituminous matter. 8. *Mineral found in a hillside of the Vindhyan range 2 miles from Katni, above limestone.* Carbonaceous shale.
Four blocks of sandstone, A and B from Taung-u, C from Kyauk-ta, and D, from Shwebo, to know if there is anything in their composition subject to rapid decay by atmospheric influences, such as gypsum, sulphur, clay, etc., which would render them unfit for building purposes.	H. Groves, Superintending Engineer, N.-W Circle, P. W. D., Burma.	Practically free from those minerals which usually are destructive to building stones, such as pyrites and gypsum. B, is quite free from gypsum, which a chemical test shows to be present in A, C, and D in very faint traces.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance.	For whom.	Result.
Specimen of "a very white stone" to know the name of the mineral.	Burn and Co., Ld., Calcutta.	The substance in question is white arsenic and is very probably an artificial product and not a mineral. If a natural product it would be of interest to know where and in what manner it occurs.
Six specimens of Rocks from the Gaya district, for classification.	...	1. Kaolin, almost China clay. 2 and 3. Amphibolites. 4. Tourmaline. 5. Tourmaline and iron ore grains constitute the black veins in the granite. 6. Epidote forms the greenish part of the rock, which might be called an epidote-granite.
Two specimens from Jeypore, to be named.	D. Hooper, Offg. Reporter on Economic Products to the Government of India.	The black powder seems to be an earth coloured by carbonaceous matter, while the specimens in the bag are of two kinds, actinolite and epidote. So far as I know they are of no commercial value.
Sends a boulder and wishes to know what it is.	Samuel Fitze and Co., Calcutta.	The stone in question is an amphibolite and is of no value commercially.
A specimen of elæolite syenite, containing biotite and graphite, from Salem district, Madras.	T. H. Holland, A. R. C. S., F. G. S., Deputy Superintendent, Geological Survey of India.	No. $\frac{11}{880}$, SiO_2 . . . . . . 55·08 Al_2O_3 . . . . . . 23·81 Fe_2O_3 . . . . . . 5·01 CaO . . . . . . 1·69 MgO . . . . . . ·65 Na_2O . . . . . . 9·23 K_2O . . . . . . 5·16 Graphite . . . . ·58 Loss on ignition . . . ·34 102·15
Specimens of blue crystals, from Padar, Kashmir, to know what they really are.	Major-General de Bourbel, Simla.	Crystals of corundum, in granite, of no value as gems.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Snbstance.	For whom.	Result.
Three spcimens of rocks belonging to the Pyroxenic Series of Madras.	T. H. Holland, Deputy Superintendent, Geological Survey of India.	No. $\frac{8}{283}$, *Charnockite from Hill near magazine, (central part), St. Thomas' Mount, Madras.* SiO_2 . . . . . . 75·54 Al_2O_3 . . . . . . 13·75 Fe_2O_3 . . . . . . 4·99 FeO . . . . CaO . . . . . . ·94 MgO . . . . . . ·69 K_2O . . . . . . 3·34 Na_2O . . . . . . 1·55 Loss on ignition . . . ·28 TOTAL . 101·08 Specific gravity . . . 2·672 No. $\frac{8}{280}$, *Norite, from east side of magazine, St. Thomas' Mount, Madras.* SiO_2 . . . . . . 53·57 Al_2O_3 . . . . . . 13·92 Fe_2O_3 . . . . FeO . . . . . . 15·71 CaO . . . . . . 8·13 MgO . . . . . . 3·41 K_2O . . . . . . ·70 Na_2O . . . . . . 5·31 Loss on ignition . . . ... TOTAL . 100·75 Specific gravity . . . 3·023

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance.	For whom.	Result.
		No. $\frac{9}{391}$, *Pyroxenite, from Hill west of Pallavaram, Madras.* SiO_2 . . . . . . 46·86 Al_2O_3 . . . . . . 9·80 Fe_2O_3 . . . . FeO . . . . . . 16·35 CaO . . . . . . 9·57 MgO . . . . . . 18·08 K_2O . . . . . . Traces. Na_2O . . . . . . Ditto. Loss on ignition . . . ·67 TOTAL . 101·33 Specific gravity . . 3·333
A specimen found near Gulmarg, Kashmir, for identification.	Major General de Bourbel, Umballa Cantonment.	Galena, containing a little antimony and silver.
Specimen of a coal-like substance thrown up by the earthquake of 12th June 1897, in the Goalpara District, Assam.	Secretary to the Chief Commissioner of Assam, Shillong.	Water-worn pebbles of lignite.
A specimen of coal from the workings at Palana, Bikanir State, for analysis.	Tom D. La Touche.	*Quantity received 80 lbs.* Moisture . . . . . 19·30 Volatile matter exclusive of moisture . . . 39·80 Fixed carbon . . . 35·40 Ash . . . . . ·540 100·00 *Does not cake, but sinters slightly. Ash—light brown.*
Specimens from the Khost District for identification, and if of any value.	Lieutenant G. L Carter, Commandant, Kurram Militia, Parachinar.	*Asbestos.*—Used for making rope, paper board or felt for packing steam pipes, etc., and for other purposes where an incombustible non-conducting and pliable mineral is needed.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance.	For whom.	Result.
		2. *Iron pyrites.*—(Iron disulphide, FeS_2), of no value.
Twenty Geological specimens from the neighbourhood of Kotah, to be named.	The Political Agent, Kotah, Rajputana.	1. *Limestone.*—Medicinal qualities imaginary. 2, 3, 4, 5, 7 10, 11, 12 and 20. *Chalcedony*, probably from geodes in Deccan trap. 8 and 18, *Calcite.* 6, 13, 14, 15, 16 and 17, *Jasper.* 19, *Carnelian.* 9, *Physa sp.* (2 specimens), and *Natica*, sp., probably from Intertrappean beds.
Nine specimens of rocks from the Erinpura district, Sirohi State, Rajputana, for gold and silver.	Capt. F. T. C. Hughes, I.S.C., Erinpura Irr. Force, Erinpura	1. *Dark brown ferruginous quartzose rock. Quantity received 12½ oz.* Yielded on assay 3 dwts. 14·24 grs. of fine metal (gold and silver); the gold, on parting, was found to be a trace only. 2. *Schistose purple rock, fine grained. Quantity received 21¾ oz.* Contains no gold or silver. 3. *Hæmatite schist, fine grained. Quantity received 6¾ oz.* Contains no gold or silver. 4. *Same as No. 2.* Contains no gold or silver. 5. *Probably a slag.* Yielded on assay, 1 dwt. 15·2 grs. of fine metal (gold and silver), the gold being only a trace. 6. *Fissile thin-bedded rock, containing copper. Quantity received 7½ oz.* Contains no gold or silver. 7. *Same as No. 6. Quantity received 1½ oz.* Contains no gold or silver. 8. *Siliceous banded rock.* 9. *Amygdaloidal trap.* Nos. 8 and 9 not assayed.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance.	For whom.	Result.
Twelve seals for determination.	Dr. A. F. R. Hœrnle, M.A.	1. Serpentine. 2. Steatite. 3. Ivory. 4. Sardonyx. 5. Artificial glass. 6. Sardonyx. 7. Glass. 8. Serpentine. 9. Sardonyx. 10. Spinel. 11. Lapis-Lazuli. 12. Lapis-Lazuli.
Six specimens of minerals for determination.	Lieut. Col. F. G. L. Mainwaring, 29th Punjab Infantry.	1. Azurite with malachite 2. Azurite in quartz. 3. Serpentine. 4. Ferruginous fibrous quartz, pseudomorphous after crocidolite. 5. Pinite. 6. Pinite with saussurite.
A black mineral occurring in the pegmatite veins with the mica at Nellore.	Dr. T. L. Walker, M.A., Geological Survey of India.	Columbite ; S. G. 5·748.
Specimen of a rock which forms the footwall below the reef, Chowkpazat gold mine.	C. M. P. Wright, Nankan P. O., Upper Burma.	A crushed diorite or dioritic ash.
A specimen of copper ore and a piece of copper smelted from the same, for gold and silver; also another specimen for determination and percentage of copper.	W. Pendlebury, Agent and Manager, H. H. the Nizam's Guaranteed Railways Co., Ld., Secunderabad, Deccan.	1. The ore is chalcocite with malachite; the copper contains 1 oz. 6 dwts. 3 grs. of silver to the ton, but no gold. 2. The other specimen is phyllite with malachite and contains 2·41 per cent. of copper (Cu).

List of Assays and Examinations made in the Laboratory during the past year—concld.

Substance.	For whom.	Result.
Specimen of a pebble found in some quantities at Mamve in the Kamaing township, Myitkyina district, for identification.	The Secretary to to the Financial Commissioner, Burma, Rangoon.	Red corundum.
A specimen found in the Government Forests in the Hazaribagh district.	A. E. Wild, Conservator of Forests, Bengal, Darjeeling.	Arsenopyrite.
Specimen of a rock from Assam supposed to contain tin.	E. S. Wood, Bengal Coal Co., Calcutta.	Coarse sandstone stained with oxide of iron; contains no tin.
A specimen found in the Rewah State, to know what it is.	F. C. Osler and Co., Calcutta.	Ordinary manufactured bottle glass.
Sends 8 stones at the request of Raja of Mandasa in Ganjam, picked up on Mahendragiri mountain on his estate, 5,000 feet high, to know what they are.	T. J. V. Minchin, Aska works, Ganjam, Madras.	Five of the specimens are true sapphires of very good colour; the remaining 3 are garnets.
Three nodules picked up on the Murree hills in 1896.	C. E. Pitman, C.I.E., Director General of Telegraphs.	Nodules of iron pyrites.

2. PALÆONTOLOGICAL WORK.

Dr. Fritz Noetling was in the field during the greater part of the year under review, but after his return to headquarters he was engaged chiefly in describing the fossils which he had collected in Baluchistan. A summary of his survey appears in Part II of this Report.

MIOCENE FOSSILS OF BURMA.

Afterwards Dr. Noetling resumed the description of the miocene fauna of Burma, which was shortly reviewed in the "General Report" ending 31st March 1898 (page 11). An examination of the gastropoda of this fauna con-

firms the conclusions drawn from the study of the pelecypoda, in that the fauna bears a general resemblance to the fauna living at present in the Indian Ocean rather than to that of the forms found in the miocene beds of either Australia or Europe, but it bears a close resemblance to the fauna contained in the miocene beds of Java.

SPITI FOSSILS.

DR. A. VON KRAFFT.

Immediately on his arrival at headquarters, Dr. A. von Krafft was charged with the study and determination of the rich collection of fossils which Mr. H. H. Hayden had obtained whilst carrying on surveys in Spiti during the summer of 1898. Dr. von Krafft has practically completed the examination of the fine suites of cephalopoda of the lowest trias and Muschelkalk, and has sent in preliminary notes on the same. A full account with the description of the new forms discovered will eventually be published in the Palæontologia Indica.

Notes on the triassic cephalopoda of Spiti.

The fine collections of cephalopoda brought from Spiti by Mr. Hayden were derived from the Otoceras beds, Subrobustus beds and the Muschelkalk. They form a very important contribution to our knowledge of the faunas of these horizons, especially the Muschelkalk fauna is most richly represented.

The following notes by Dr. A. v. Krafft contain a preliminary account of these fossils:—

The fossils collected in the Otoceras beds of Spiti comprise 34 species of ammonoidea, out of which 19 can be identified with species described in Prof. Diener's Memoirs. Eleven species are new.

Otoceras beds. Genera absent.

The genera *Nautilus*, *Nannites*, *Flemingites*, *Hungarites* and *Prionolobus*, though formerly obtained in this horizon, do not appear in Mr. Hayden's collection.

Geological position of Danubites ellipticus ascertained.

As regards the geological position of *Danubites ellipticus*, which according to Prof. Diener was doubtful,[1] there seems no longer any doubt that this species occurs in the *Otoceras* beds, since two specimens have been obtained 5 miles S. of Ensa in the *Otoceras* beds together with *Otoceras sp.*

New species.

Among the new species three species of *Danubites* may be specially mentioned, *viz.*, two species allied to *Danubites* (*Gyronites* Waagen) *radians*, Waagen, and one species related to *Danubites* (*Gyronites* Waagen) *plicosus*, Waagen.

Several species occurring in the *Otoceras* beds are supposed by Prof. Diener to be related to forms of the lower ceratite limestone of the Salt Range (Diener, l. c., p. 176), and the same is found to be the case with *Danubites* nova sp. aff. *D. plicosus*, Waagen.

As to the two species compared with *Danubites radians*, Waagen, their

[1] l.c., p. 186.

occurrence in the *Otoceras* beds is a surprising fact, seeing that the Salt-Range species appears in the ceratite sandstones which have been correlated with the *Subrobustus* beds.

The most interesting form among the new types is probably *Meekoceras* nova sp. aff. *Meekoceras rotundatum*, E. v. Mojs. *Meekoceras rotundatum*, E. v. M., occurs in the Olenek beds with *Ceratites subrobustus*, *Dinarites glacialis*, etc., which are the equivalent of the Subrobustus beds of the Himalayas. The occurrence of a nearly allied form in the *Otoceras* beds of Spiti is therefore somewhat unexpected. However, the likeness of both species is most striking, although the Spiti form will have to be considered a new species.

List of the *Ammonites* collected from the *Otoceras* beds:—

Danubites ellipticus Diener (2)[1].
" *planidorsatus*, Diener (6).
" nova sp. ex aff. D. (*Gyronites* Waagen) *radians* (6).
" nova sp. ex aff. *D. radians*, Waagen (1).
" nova sp. ex aff. *D. plicosus*, Waagen (1).
" ? nova sp. ind. (3).
" ? nova sp. ind. (1).
Medlicottia Dalailamæ, Diener (1).
" sp. ind. (1).
Prosphingites, sp. ind. (1).
Proptychites Markhami, Diener (12).
" sp. ind. (2).
Vishnuites Nalambha, Diener (1).
Ophiceras Sakuntala, Diener (12).
" *tibeticum*, Griesbach (5).
" *demissum*, Opp. (6).
" *Dharma*, Diener (2).
" *Chamunda*, Diener (16).
" *platyspira*, Diener (2).
" *serpentinum*, Diener (8).
Otoceras Woodwardi, Griesbach (9).
" *Clivei*, Diener (2).
" nova sp. (1).
" sp. (many fragments).
Koninckites cf. *Vidarbha*, Diener (1).
Kingites Varaha, Diener (9).
" sp. aff. *Varaha*, Diener (1).
Meekoceras Hodgsoni, Diener (3).
" nova sp. aff. *Hodgsoni* (+), Diener (1).
" *boreale*, Diener (1).

[1] Number of specimens.

Meekoceras cf. *boreale*, Diener (1).
„ sp. ind. aff. *plicatili*, Waagen, Diener, l. c., Pl. XV, p. 6 (1).
„ nova sp. ex aff. *Meekoceras rotundatum*, E. v. Mojs. "Arktische Triasfaunen", Pl. X, fig. 16 (2).
„ nova sp. ind.
„ nova sp. ind.
Lekanites (?) nova sp. ind. (5).

Subrobustus beds.—The collections derived from the subrobustus beds of various localities in Spiti comprise 34 species of Ammonoidea and 3 species of Nautiloidea. Out of these one *Pleuronautilus* and 10 *Ammonites* are new; the greater part of the remaining species can be identified more or less satisfactorily with species described by Professor Diener in his Memoir, Ser. XV, Vol. II, part I of the Palæontologia Indica. Of the 20 species described in that Memoir, 15 are present in Mr. Hayden's collections, none of the genera being absent.

The following is a list of the fossils collected :—

Pleuronautilus, nova sp. (2).
Nautilus, sp. ind. ex aff. *N. Palladii*, E. v. Mojs. (1).
Orthoceras sp. ind. (9).
Danubites nivalis, Diener (21).
„ *Purusha*, Diener (7).
„ *Kapila*, Diener (2).
„ aff. *Kapila*, Diener (1).
„ nova sp., group of the *Danubites Hamalayanus*, Diener 29).
„ ? nova sp. ind. (1).
„ ? nova sp. ind. (1).
Hedenstrœmia Mojsisovicsi, Diener (23).
„ cf. sp. ind. ex aff. *Hed. Mojsisovicsi*, Diener, l. c., Pl. XXII, fig. 2. (1).
„ nova sp. aff. *Mojsisovicsi*, Diener (1).
„ nova sp. ind. (1).
Meekoceras, nova sp. ind. (1).
„ sp. ind. (1).
Proptychites cf. sp. ind. ex aff. *P. obliqueplicato*, Waagen, Diener, Pl. XVII, fig. 3 (1).
„ sp. ind. (1).
Flemingites sp. aff. *Salya*, Diener (1).
„ cf. *Salya*, Diener (1).
„ *Rohilla*, Diener (17).
„ aff. *Rohilla*, Diener (1).

Flemingites nova sp. ex aff. *Flemingites Rohilla*, Diener (2).
„ sp. ind. ex aff. *Fl. trilobato*, Waagen, Diener, Pl. XVII, fig. 2 (11).
„ nova (?) sp. aft. *Flem. Flemingiarius*, Waagen (4).
„ nova sp. ind. (1).
„ nova sp. ind. (2).
Aspidites superbus, Waagen (2).
„ cf. *superbus*, Waagen (1).
„ (?) nova sp. (1).
Koninckites Yudishthira, Diener (12).
Lekanites sp. aff. *Lekanites undatus* (?) Waagen (1).
Nannites Hindostanus, Diener (4).
Tirolites nova sp., group of the *Tir. spinosi*, E. v. Mojs. (2).
Prionolobus nova sp., group of the *Prionolobus atavus*, Waagen (2).
Acrochordiceras sp. ind. (1).
Ceratites sp. ind. (2).
Ceratites subrobustus, E. v. Mojs. (2).

Genera hitherto unknown from the Himalayan subrobustus beds.

Among the genera of this collection four had not previously been found in this horizon, *viz.*:—

Nannites,
Acrochordiceras,
Prionolobus, and
Tirolites.

The species of *Nannites* described by Professor Diener having been derived from the *Otoceras* beds, this genus appears to be common to both *Subrobustus* and *Otoceras* beds. The specimens collected by Mr. Hayden are even specially identical with *Nannites Hindostanus*, Diener. It seems, however, not impossible that the geological position of this genus was hitherto not sufficiently ascertained.

Occurrence of Tirolites.

The presence of *Tirolites* is specially interesting as this genus had not only never been obtained in the Himalayas, but its absence was even considered by Dr. E. v. Mojsisovics and Professor Diener to be a peculiarity common to the Indian and the Arctic trias.

Correlation between subrobustus beds of the Himalayas and the ceratite sandstones of the Salt-range.

Professor Diener in his Memoir on the Cephalopoda of the lower trias correlated the *Subrobustus* beds of the Himalayas with the *Ceratite* sandstone of the Salt-range, enumerating eight species which are either intimately related or probably identical. The author considered the relationship between both faunas all the more conspicuous as he regarded the fauna then known from the *Subrobustus* beds as comparatively scanty. He therefore expected that further researches would show this relationship in a still more striking manner.

However, this hope has scarcely been realised. There is indeed one form among the species collected by Mr. Hayden, which points to the correlation of the *Subrobustus* beds with the *Ceratite* sandstones, *viz.*, *Flemingites* nova (?) sp. aff. *Flem. Flemingianus*, Waagen, and the discovery of this form is no doubt a most important point.

But on the other hand a great many species and even genera still remain absent, and seeing that out of 10 new species recently collected in the *Subrobustus* beds, only one resembles a Salt-range form, there seems little hope that many of the types of the *Ceratite* sandstones may be met with in the *Subrobustus* beds of the Himalayas. We therefore come to the conclusion that the relationship of the two faunas is not so extensive as has been expected.

Muschelkalk.—The collections from the muschelkalk of Spiti comprise 58 species of *Ammonoidea* and 7 species of *Nautiloidea*, out of which 48 *Ammonoidea* and 4 *Nautiloidea* can be identified with species which had already been described by Professor Diener in Ser. XV, Vol. II, Part 2 of the Palæontologia Indica, while 13 species are new.

The following species are represented in the collection :—

Dinarites (?) spec. ind. (1).[1]
Ceratites sp ind. cf *Cer Wetsoni*, Opp. (1).
,, *Voiti*, Opp. (1).
,, cf. *Voiti*, Opp. (1).
,, *Ravana*, Diener (4)
,, nova sp. ex aff. *Cer. Ravana*, Diener, l. c., Pl, II, fig. 4 (5).
,, nova sp. ex aff. *Cer. Ravana*, Diener, Pl. II, fig 6 (4)
,, *Hidimba*, Diener (1).
,, *Airavata*, Diener (2).
,, cf. *Airavata*, Diener (2).
,, *Dungara*, Diener (1).
,, *Vyasa*, Diener, Pl. VI, fig. 2, not fig. 1 (1).
,, *Thuillieri*, Opp. (8, many fragments).
,, *Thuillieri* varietas, Pl. I, fig. 2 (3).
,, *Himalayanus*, Blanford (1).
,, aff. *trinodosus*, E. v. Mojsisovics (1).
,, aff. *superbus* E. v. Mojs. (1).
,, aff. *Abichi*, E. v. Mojs. (1).
,, cf. *Kamadeva*, Diener (1).
,, *horridus*[2], Opp. (3).

[1] Number of specimens.

[2] Dr. E. v. Mojsisovics has twice erroneously mentioned this species as *Ceratites truncus*, Opp. "Cephalopoden Medit. Trias provinz." Abh. d. K. K. Geol. R. A. in Wien, X, 1882, p. 42, and "Arktische Trias faunen", Mem. de l'academie impér. des sciences de St. Petersburg, ser. VIII, T. XXXIII, No. 6, 1886, p. 21. The same mistake reappears in Professor Diener's Memoirs, l.c., p. 26.

Ceratites nova sp ex aff. *Cer. horidus*, Opp. (1).
„ nova sp. from the group of the *Ceratites subrobusti*, E. v. Mojs. (1).
„ nova sp. (Diener, l. c., Pl. VI, fig. 1, not fig 2) (11),
„ nova sp. ind. (2).
„ nova sp. ind. (1).
Japonites nova sp. ind. (2).
„ ? *Dritaráshtra*, Diener, sp. (1).
Trachyceras aff. *longobardicum*, E. v. Mojs. (1).
„ sp. ind. group of the *Trachycerata margaritosa*, E. v. Mojs. (1).
„ nova sp. ind. ex aff. *Trachyceras Reitzi*, E. v. Mojs. (1).
Acrochordiceras Damesi, Nœtling (16).
Iscalites Hauerinus, Stol. (14).
Proarcestes nova sp. ind. ex aff. *Proarcestes Bramantei*, E. v. Mojs. (1).
Joannites aff. *diffissus*, v. Hauer (1 or 2).
Meekoceras Khanikofi, Opp. (16, several fragments).
„ cf. *proximum*, Opp. (1).
Gymnites Jollyanus, Opp. (26).
„ *Kirata*, Diener (4).
„ *Vasantasena*, Diener (4).
„ *Lamarki*, Opp. (5).
„ nova sp. ind. (see p.) (1).
Buddhaites Rama, Diener (17).
Sturia Sansovinii, E. v. Mojs. (3).
Ptychites rugifer, Opp. (24).
„ *Tibetanus*, E. v. Mojs. (1).
„ *Mangala*, Diener (2).
„ *Sukra*, Diener (3).
„ *cognatus*, Opp. (2).
„ *asura*, Diener (2).
„ *govinda*, Diener (1).
„ *impletus*, Diener (7).
„ *Sahadeva*, Diener (1).
„ *Sumitra*, Diener (1).
„ cf. *Sumitra*, Diener (4 and several fragments).
„ nova sp. ind. ex aff., *P. Malletianus*, Opp., Diener, l.c., Pl. XVII, fig. 2 (1).
„ *Gerardi*, Blanford (3).
„ *Everesti*, Opp. (3).
„ *Vidura*, Diener (11).

Ptychites Drona, Diener (2).
,, *cochleatus*, Opp. (2).
,, *cochleatus*, Opp. varietas (5).
,, *Mahendra*, Diener (2).
Nautilus cf. *Griesbachi*, Diener (2).
,, *spitiensis*, Stol. (3).
,, nova spec., ind. (6).
Pleuronautilus nova sp. ind. aff. *P. Esinensis*, E. v. Mojs. (2).
,, nova sp. ind. (1).
Orthoceras cf. *Campanile*, E. v. Mojs. (fragments).
,, sp. ind. ex aff. *O Campanile*, E. v. Mojs. (fragments).

Genera absent.

Of the genera previously mentioned as represented in the main mass of the Himalayan muschelkalk, only two are absent from Mr. Hayden's collections, *viz.* :—

Novum genus ex fam. *Arcestidarum*, and
Lobites,

the presence of the latter genus being considered by Professor Diener as doubtful.

Professor Diener described one species of the genus *Danubites, viz., Danubites Dritarashtra.* This species is probably present in Mr. Hayden's collection, but as I rather believe it to belong to the genus *Japonites*, I have placed it in the foregoing list among the species of that genus. This question will be found more fully discussed below (p. 20).

Genera not known hitherto to occur in the muschelkalk of the Himalayas.

While only one or two of the genera known from this horizon can be said to be absent from the collection, four genera appear which had as yet not been noticed in the Himalayan muschelkalk, *viz.* :—

Dinarites (?),
Trachyceras,
Joannites (?), and
Pleuronautilus.

The presence of the genus *Dinarites* is uncertain as there is only a fragment of a body chamber in the collection, which, although recalling certain *Dinarites* of the group of the *D. circumplicati*, does not permit of an accurate generic determination.

Specimens of the genera *Trachyceras* and *Joannites* had previously been discovered by Professor Diener in a crinoid limestone in the Shal-Shal cliff section, which follows immediately above the top-most Ptychites beds of the muschelkalk, and E. v. Mojsisovics considers these specimens to be "very nearly allied to, if not identical with, Alpine forms from the zone of the *Trachyceras Aonoides*."[1]

[1] Diener, l.c., p. 99.

The specimens of *Joannites* collected by Mr. Hayden bear the greatest resemblance to *Joannites diffissus*, v. Hauer, which species occurs in the Carnic stage of the Alpine trias. Thus it is quite conceivable that the *Joannites* recently collected in Spiti might also have been derived from beds overlying the muschelkalk.

As regards the genus *Trachyceras*, several species occur in the collection. One of them is apparently closely related to *Trachyceras Aonoides* v. Mojs., and accordingly what has been said above on the possible origin of *Joannites* aff. *diffissus* v. Hauer applies to this species of *Trachyceras* also.

But another species of *Trachyceras* is allied to *Trachyceras longobardicum* v. Mojs. and a third one to *Trachyceras Reitizi*, v. Mojs., both occurring in the ladinic stage of Europe. Seeing that this stage has never been traced in the Himalayan trias as a distinct horizon between the main mass of the muschelkalk and the "crinoid limestone with fossils" of the upper Carnic stage, the two species of *Trachyceras* under consideration cannot but have been derived from the main mass of the muschelkalk.

Accordingly the occurrence of the genus *Trachyceras* in the Indian muschelkalk is beyond doubt, although this genus had previously only been met with in higher stages of the triassic system.

In summing up what has been said above, we may so far consider the presence of the genera *Joannites* and *Dinarites* as doubtful, while *Pleuronautilus* and *Trachyceras* undoubtedly occur in the muschelkalk of Spiti.

Presence of Isculites ascertained.

Seeing that Professor Diener expresses doubt as to the occurrence of *Isculites* among the genera represented in the Indian muschelkalk, it is an interesting fact that no less than 14 specimens of *Iscalites Hauerinus* were collected by Mr. Hayden from this horizon in Spiti.

Species nearly allied to, or identical with, European forms.

A number of species bear a close relationship to European types. Among these *Ceratites* aff. *superbus* is represented by one well-preserved specimen, which exhibits exactly the same characteristic sculpture as fig. 5, Pl. XXXIII, of Mojsisovics "Cephalopoden der medit. Trias Provinz," and differs from the same figure but slightly in shape.

Three specimens of *Ceratites* must be looked upon as intermediate forms between *Cer. Thulleri*, Opp., and its nearest ally, *Ceratites trinodosus* E. v. Mojs. In all three the involution takes place inside the spiral line of lateral tubercles.[1]

The sculpture of one of these specimens is similar to that of *Ceratites Thuillieri*, Opp. A second specimen recalls *Cer. trinodosus* in so far as along about one-third of the last whorl four lateral tubercles correspond to nine siphonal tubercles. The third specimen differs from the genuine *Ceratites trinodosus* by incised saddles only.

[1] E. v. Mojsisovics "Ceph. d. Med. Trias Provinz." Abhandlungen d. Geol. R.A., Vienna, Vol. X, p. 30.

Ceratites aff. *Abichi*, v. Mojs., the only representative of the group of the *Ceratites binodosi* as yet known from the muschelkalk of the Himalayas, *Trachyceras* aff. *longobardicum*, E v. Mojs., *Proarcestes*, nova sp. ind. ex aff. *Proarcestes Bramantei*, E. v. Mojs., *Joannites* aff. *Joannites diffissus* v. Hauer and *Pleuronautilus* nova sp. ind. aff. *Pleuronautilus Esinensis*, E. v. Mojs., are equally remarkable as being species having more or less close affinity to European forms.

Joannites diffissus had been formerly mentioned by Salter[1] and Stoliczka[2] as occurring in the triassic deposits of the Himalayas, but the determinations of the respective ammonites were subsequently shown to have been incorrect.[3] Yet the occurrence of a *Joannites* very closely related to *Ioannites diffissus* in the muschelkalk[4] of Spiti is for all that a matter of fact. One specimen in the collection exhibits perfectly the characters of the species in question, and were it not for its somewhat more compressed shape, it would be impossible to distinguish the Himalayan from the European specimen. On the last whorl, which is chambered through half its length, two flat contractions are seen. The sutures are arranged in an arch-like line, formed by more than six saddles. The umbilicus being damaged, the full number of saddles cannot be made out, six only being traceable; but it probably amounts to seven or eight. Saddles bipartite, lobes divided at their base by prominent tubercles. Siphonal tubercle not traceable.

Acrochordiceras Daimesi, Nœtling, not hitherto recorded from the Indian muschelkalk, is represented in the collection by 16 specimens. These vary greatly in shape and sculpture of the shell, and I believe *Acrochordiceras Balarama*, Diener, to be an extraordinarily stout variety of *Acrochordiceras Daimesi*.

New species.

Leaving out those species which are probably only varieties of forms already known, we may consider 12 or 13 species of *ammonoidea* as new, *viz.*:—

5 *Ceratites*,
1 or 2 *Japonites*,
1 *Trachyceras*,
1 *Proarcestes*,
1 *Gymnites*,
1 *Nautilus*, and
2 *Pleuronatilus*.

As I hope to be able to describe and figure these species later on, I content myself in the present preliminary account with mentioning such facts as have a bearing on the descriptions given by Professor Diener, l. c.

[1] Palæontology of Niti, p. 64, Pl. VII fig. 5.
[2] Mem. Geol. Survey of India, Vol. V, Pt. I, p. 53, Pl. V, fig. 4.
[3] E. v. Mojsisovics, l c., p. 69; Diener, l.c., p. 84.
[4] Or possibly in beds belonging to the upper Carnic stage (see above).

The two specimens figured on Pl. VI in Professor Diener's Memoir as *Ceratites Vyasa* are, I believe, two different species. Professor Diener's description of the inner whorls of *Cer. Vyasa* (l. c., Pl. VI., 19 and 20) being apparently chiefly based on observations on the specimen represented in fig. 2, Pl. VI, I propose to confine the name *Ceratites Vyasa*, to the latter.

Pl. VI, fig. 1, is a different species with inner whorls which in transverse section and sculpture are quite unlike those of the *Cer. Vyasa* s.s. In early stages of growth the whorls of the present species recall *Ceratites* nova sp. ex aff. *Cer. subrobustus*, E. v. Mojs., Diener, l.c., Pl. V, fig. 6, although flatter sides, a well-marked umbilical margin and the absence of a keel are considerable points of difference. The characters which give the species a resemblance to *C. subrobustus* gradually disappear and pass into a sculpture consisting of single ribs, increasing in bulk on the chambered portion of the shell and decreasing on the body-chamber. The latter is supposed to be smooth near the aperture.

As has been mentioned above, *Danubites Dritarashtra*, Diener, with all probability belongs to the genus *Japonites*. This statement appears to be justified by the following facts.

One of the species of *Japonites* in the collection consists of very slowly increasing whorls, only slightly overlapping each other, the sides are covered with strong radial ribs which die out near the siphonal edge, where some of them are found to bifurcate. The septa are very distant from each other, the saddles unusually broad, the first auxiliary lobe coincides with the umbilical margin. For the rest the sutures are similar to those of other species of *Japonites*, especially in the shortness of the second lateral lobe.

I believe this species of *Japonites* to be identical with the specimen described by Professor Diener as *Danubites Dritarashtra* for the following reasons: both specimens have the same shape, the same involution, and the same sculpture. As to the latter I may mention that bifurcating ribs can be seen on Professor Diener's type-specimen. Moreover, in both specimens the septa are unusually distant and the sutures similar to one an other, in so far as the second lateral lobe is much shorter than the first and the auxiliary lobe coincides with the umbilical margin.

There are but two differences noticeable. Diener's type-specimen shows unincised saddles, while in the *Japonites* under consideration the saddles are incised. Besides this, the auxiliary lobe is shorter in Diener's type-specimen than in the latter.

Unfortunately I did not succeed in developing the sutures of the inner whorls of this *Japonites* and thus further researches as to the correctness of my supposition were impossible. For this reason I abstain from changing the present nomenclature, hoping that further researches will reveal more specimens from which it will be possible to decide the question.

Professor Diener on pages 95 and 96 of his Memoir, when comparing the faunas of the muschelkalk of the Spiti and the Niti area, enumerates 24 more important ammonites which were then only known from Niti. Out of these 10 have recently been collected in Spiti, and the number of forms peculiar to the Niti area is therefore restricted to 14, *viz.*:—

Differences between the faunas of the Niti and Spiti area.

Ceratites Visvakarma, Diener (1)[1].
,, sp. ind ex aff. *Cer. Middendorfi* (1).
,, nova sp. ind. ex aff. *C. Geminato* (1).
,, *Arjuna*, Diener (2).
,, nova sp. ind ex aff. *C. Wetsoni* (1).
Japonites Sugriva, Diener (1).
,, *Chandra*, Diener (1).
Meekoceras Kesava, Diener (1).
,, *Gangadheva*, Diener (2).
,, affine v. Mojs. (2).
,, *Rudra*, Diener (1).
,, *Nalikanta*, Diener (3).
,, *Nanda*, Diener (1).
,, *Srikanta*, Diener (3).

Seeing the small number of individuals of each species found, the absence of these 14 species in the collections as yet made in Spiti is scarcely of any importance, as these fossils are evidently rare in Niti also.

Professor Diener also compares the trias of the Himalayas to the Alpine trias, and emphasizes the fact that nowhere in the Himalayas have deposits of ladinic or lower carnic age been met with between the muschelkalk and the Daonella beds. He therefore suggests[2] that either there is no palæontological representative of the ladinic stage, or that the muschelkalk in the Himalayas may contain also some ladinic elements. The author comes to the conclusion that there is little to support the latter supposition.

Probable representation of the ladinic stage in the Muschelkalk of the Himalayas.

With reference to the above I may state that there are a few species in Mr. Hayden's collection which I cannot but correlate with certain types peculiar to the ladinic stage of Europe, *viz.*:—

Trachyceras sp. aff *longobardicum*, E. v. Mojs.
,, nova sp. aff. *Trachyceras Reitzi*, E. v. Mojs.
Pleuronautilus nova sp. ind. aff. *P. Esinensis*, E. v. Mojs.

It is true that the number of ladinic types is so far very small, but their

[1] Number of specimens collected.
[2] l. c., p. 99.

importance seems to be all the greater. On the strength of the occurence of these species in the muschelkalk of Spiti, I feel much inclined to look upon the Indian muschelkalk as including the ladinic stage. This supposition, however, needs further corroboration, and such will certainly be available if the Indian muschelkalk has actually a greater stratigraphical range than has hitherto been assumed.

PALÆONTOLOGICAL WORK DONE IN EUROPE.

Indian fossils described in Europe.

At the present moment there are large collections of fossils belonging to this Department still in the hands of scientists in Europe, who are describing the same for publication in the Palæontologia Indica. The following is a list of the scientists who have kindly undertaken to do this work for India, and the fossils under description:—

In England—

DR. J. W. GREGORY, British Museum.	Jurassic fossils of Cutch.
DR. F. L. KITCHIN, Geological Survey of England and Wales.	Ditto.
MR. PHILIP LAKE, M.A., St. John's Coll., Camb.	Silurian and Devonian fossils of the Himalayas.

In Austria—

PROF. W. WAAGEN, University of Vienna.	Salt-range fossils.
PROF. UHLIG, D. Ph., University of Prague.	Jurassic fossils of the Himalayas.
DR. F. KOSSMAT, K. K. Geologische Reichsanstalt.	Cretaceous fossils of Assam.

Professor E. Suess.

In conclusion, I wish to draw attention to the generous and unwearied help and advice which has been given to us for so many years by Professor Eduard Suess, the learned President of the Imperial Academy of Science of Austria. Without any other reward than the knowledge of having advanced the cause of science, he has befriended the Geological Survey of India, receiving our collections, placing them into the most competent hands for description, and keeping a conscientious account of the necessary expenditure incurred for publication and all that is connected with the work required to be done in Europe, for all of which the Department owes a debt of deep gratitude to Professor Suess.

3. SPECIAL WORK; OFFICERS ON DUTY IN EUROPE.

Earthquake inquiry: Memoirs, Vol. XXIX. in progress.

Mr. Oldham was placed on duty in Europe for 14 days in extension of privilege leave, for the purpose of consulting certain books on earthquakes which were not accessible in India. The time was spent in the libraries of the Geological Society and of the British Museum, and the results have been incorporated in the report on the earthquake of 1897 which is now in a forward state, 200 pages or about one half having already been passed to press. The investigation of this earthquake has yielded important scientific results; fresh light has been thrown on the mechanism of the production of earth fissures and landslips, and of the rotation of pillars, a subject which has been productive of much speculation and of many theories. The measurements of the numerous objects caused to revolve more or less on their axis by this earthquake has shown that the phenomenon must be due to a form of movement of the ground to which the term vorticose is not inapplicable, though it must be understood in a different sense to that which it conveyed to those authors who have contended that vorticose motion in an earthquake is a physical impossibility.

The discussion of the European records of this earthquake have led to an important suggestion regarding the manner of propagation of the earthquake motion. Three phases in the records are recognised; of these the first two are due to condensational and distortional waves transmitted through the earth, and from the so called preliminary tremors; the great undulations, on the other hand, are surface waves transmitted round the surface of the earth, and the rate of propagation as measured between the place of origin and Europe is the same as the observed rate of travel of the earthquake shock in India.

Madras Petrology: MR. T. H. HOLLAND.

Whilst in Europe on privilege leave during last year, Mr. Holland took the opportunity of examining the collection of rocks now preserved in the Muséum d'Histoire Naturelle of Paris and obtained by Leschenault de la Tour from the Madras Presidency early in the century. These rocks had previously been described by Professor Lacroix in 1891, and the publication of his elaborate memoir demonstrated the existence in South India of many remarkable types previously unknown to us. In our subsequent attempts to identify the rocks described by Lacroix a difficulty arose through their having been represented to be generally derived from "the neighbourhood of Salem," for many of the types strikingly agreed with forms which have recently been obtained in other and distant parts of the Salem district as well as in the adjoining district of Coimbatore. To settle this point definitely, Mr. Holland made a careful examination of the Leschenault collection, and reports that we can now with fair certainty identify all the types described by Professor Lacroix.

Many of the old labels attached to the specimens in Paris being found to

bear the names of villages near which some of our rocks have been obtained, became the key sometimes to very interesting information. Specimens of corundum in its anorthite matrix, for instance, labelled "une lieue et demie environ du village de Tsholasiramani," agreed precisely with the material employed by Count de Bournon for his classical memoir on corundum and indianite (anorthite), and with the material obtained by Messrs. Warth and Middlemiss from Sithampundi, near Solasiramani (11° 14′; 77° 56′) in the Salem district. It is interesting to have established beyond reasonable doubt the original home of corundum, which was so named on account of its Indian origin and whose natural history is, on account of the large number of occurrences recently discovered *in situ*, now creating considerable interest amongst mineralogists.

Amongst other specimens in the Leschenault collection, those showing the *aqua-marine* in its matrix are interesting because of their agreement with the pegmatites obtained in and near the reputed beryl mine of Padyur (Pattalai) in the Coimbatore district. Leschenault's specimens are labelled "Pataly," and in the account of his travels he describes the mining operation then being carried on by Mr. Heath (1818). There is therefore no reason now for doubting the accuracy of the local traditions about the mine from which Heath is reported to have obtained fine gem stones. Additional interest is attached to these circumstances by the discovery of *chrysoberyl* in the corundum-bearing pegmatites of the same neighbourhood, and Mr. Holland suggests that the pit, which was abandoned when Heath left the service of the East India Company, be carefully examined in the light of our more precise knowledge concerning the mode of occurrence of the aqua-marine.

To his memoir on the geology of "the neighbourhood of Salem,"[1] reviewed in my last annual report, Mr. Holland has now appended a translation of Leschenault de la Tour's geological observations, with a series of explanatory notes summarising to date their relation to subsequent and recent investigations.

We are greatly indebted to the courtesy of Professors Fouque and Lacroix in giving Mr. Holland full facilities for examining the Leschenault collection in Paris, Professor Lacroix having also generously permitted him to make a microscopic examination of the sections employed in the preparation of his now well-known memoir.

4. PUBLICATIONS.

The following publications were issued during the past twelve months :—

Manual of the Geology of India.

PART I, CORUNDUM, by T. H. HOLLAND, has been issued since the publication of last year's General Report.

[1] Will be published in Mem. Vol. XXX.

Memoirs. Volume XXVIII, Part 1, was published during this financial year, containing the following papers :—

1. Notes on the Geological Structure of the Chitichun Region, by Dr. Carl Diener.
2. A Note on the Allahband in the North-West of the Runn of Kuchh, by R D. Oldham (1 plate).
3. Geology of parts of the Myingyan, Magwe and Pakokku districts, Burma, by G. E. Grimes (with 2 plates).
4. The Geology of the Mikir Hills, in Assam, by F. H. Smith (with 1 plate).
5. On the Geology of Tirah and the Bázár Valley, by H. H. Hayden (with 2 plates).

Palæontologia Indica. Title page, contents and appendix to the Palæontologia Indica, Series XV, Vol. II, Himalayan Fossils, was issued during the summer of 1898.

Reports of the Inspector of Mines. Mr. Grundy, the Inspector of Mines in India, sent in the following reports, which were published during the year :—

1. Annual Report for the year ending 31st December 1897.
2. Report on the Inspection of the Salt Mines, etc.
3. Report of the Inspection of the Khost and Sháhrig Coal Mines, Baluchistan.

Library.—The additions to the library during the year 1898-99 amount to 1,810 volumes and parts of volumes, of which 1,112 were acquired by presentation and 698 by purchase.

Personnel : Curator.—Mr. H. H. Hayden was Curator of the Geological Museum and Laboratory from 1st to 26th April 1898. Dr. T. L. Walker was Curator of the Geological Museum and Laboratory from 27th April to 31st October 1898. Mr. C. S. Middlemiss was Curator of the Geological Museum and Laboratory from 1st November 1898 to 31st March 1899.

Deaths.—Mr. G. E. Grimes died at Thayetmyo in Burma on the 11th April 1898.

Appointment.—Dr. A. Krafft von Delmensingen was appointed by Her Majesty's Secretary of State for India to be an Assistant Superintendent of the Department, and joined on the 13th January 1899.

Officers on leave.—Mr. C. S. Middlemiss was on privilege leave from 1st April to 15th June 1898.

Mr. R. D. Oldham was on privilege leave from the 16th July to 28th October 1898 (including 14 days on duty in England).

Mr. T. H. Holland was on privilege leave from the 28th July to 27th October 1898 (including 7 days on special duty in Paris).

Sub-Assistant Hira Lal was on furlough from 1st April 1898 to 31st March 1899, in continuation of the two years' furlough granted him from the 6th September 1897.

Selection of candidates; Dr. W. T. Blanford, F.R.S.

Only one new appointment to the Department, that of Dr. A. von Krafft, was made during the past year. The selection was made at the request of the Secretary of State for India by Dr. W. T. Blanford, F.R.S., late of the Geological Survey of India. I take this opportunity of saying that much of the good work which has been done of late by the Department is in part owing to the conscientious selection of men for the Department by Dr, Blanford. The task of selection must always be attended by risk and difficulty, but Dr. Blanford has ever most loyally worked in the interest of his old department and shirked no pains to obtain the best men procurable, which task has become year by year more difficult, owing to the small pay and smaller chances of promotion offered.

PART II.—FIELD PARTIES.

Distribution of Officers.

During the year ending 31st March 1899 the Officers of the Department were distributed as follows :—

SUPERINTENDENTS.

Mr. R. D. Oldham	Head-quarters and 3 months' privilege leave during recess; Rewa during the cold season.
„ T. H. D. LaTouche	Head-quarters during the recess ; Western Rajputana during cold season.
„ C. S. Middlemiss	Head-quarters ; in charge of Museum and Laboratory from 1st November 1898 ; deputed to Naini Tal in September 1898 to examine the landslip of the 17th August last.

DEPUTY SUPERINTENDENTS.

Mr. P. N. Bose	Head-quarters during recess ; Central Provinces during cold weather.
„ T. H. Holland	Bangalore during recess; and 3 months' privilege leave; In charge of Mica party during cold season.
„ P. N. Datta	Head-quarters.
„ F. H. Smith	Head-quarters during recess; Central Provinces during cold weather.

ASSISTANT SUPERINTENDENTS.

Mr. H. H. Hayden	Spiti during hot weather and rains; with Mica party during cold weather.

Mr. E. Vredenburg . . . Head-quarters during recess; with Seistan Mission since November 1898.

Dr. T. L. Walker . . . Head-quarters during recess in charge of Museum and Laboratory till 31st October 1898; with Mica party during cold weather.

,, A. von Krafft . . . At head-quarters since date of joining.

PALÆONTOLOGIST.

Dr. Fritz Nœtling . . In Baluchistan and Salt Range from May 1898 to December 1899. Since then head-quarters.

SUB-ASSISTANTS.

Lala Kishen Singh . . Head-quarters during recess; with Mica party during cold weather.

Division of work.—Geological surveys must necessarily have a close bearing to inquiries of an economic nature; that is to say, the results obtained by geologists during what might appear to be a purely scientific quest, have often a direct relation to economic developments. Indeed, so-called economic geology can never be entirely separated from the purely scientific side of the survey, and, properly speaking, the entire range covered by geological research is of a scientific nature.

Nevertheless, I have endeavoured to divide the work of the Department as much as possible, and whilst the majority of the officers were engaged in geological mapping, one party, consisting of three officers and a sub-assistant, was kept entirely for an economic enquiry, the mineral MICA having been selected for special study, the results to be embodied in the next "part" of the "Manual," which, it is expected, will be issued during the next year.

A. Economic Inquiries.

1. MICA.

A large number of notes on the occurrence of mica in the crystalline and schistose rocks of India had already been collected by Mr. T. H. Holland and others during previous surveys, and it was thought that a well equipped party of three Officers of the Department could so far complete the study of the mineral during one field-season as to make it possible to compile a hand-book on our present state of knowledge of mica. To visit absolutely every locality in India where the mineral occurs, would have required years of work, and the results obtained would probably have been quite out of all proportion small in comparison with the expended labour.

It was decided that it would suffice to study the mineral in the tracts where it occurred most abundantly and where the greatest facilities for its

study were obtainable, which of course are to be found where the mineral is already being won in pits and mines.

Personnel of the Mica party.

The control of the work was placed in the hands of Mr. T. H. Holland, with whom were Mr. H. H. Hayden and Dr. T. L. Walker as assistants; Sub-Assistant Lala Kishen Singh was also attached to the party and proved very useful. Dr. T. L. Walker was posted to the Nellore district, whilst Messrs. Holland and Hayden with the Sub-Assistant worked in the Hazaribagh and Gya districts of Bengal. Mr. Holland had started the inquiry in Nellore, before visiting the Bengal localities. Mr. Holland has drawn my attention to the excellent work done by Messrs. Hayden, Walker and Lala Kishen Singh. He has sent in the following preliminary report on last season's operations:—

Bengal Area.

Distribution of the schist belt.

The mica-producing belt, some 12 miles in width, stretches for about 60 miles in an east-north-east—west-south-west direction obliquely across the junctions of the three districts Gaya, Hazaribagh and Monghyr. The belt roughly coincides with the broken ground forming the northern fringe of the Hazaribagh plateau, where the rivers, flowing from the high and uniform mass of old gneiss, cut deep gorges into the heterogeneous and irregular formations of soft schist and hard gneissose granite.

Excluding the recent superficial deposits, the rocks exposed within this area include (in probable order of age) the following groups:—

6. Talchir sediments.
5. Diabase dykes.
4. Mica-bearing pegmatites.
3. Hornblendic gneissose granite, the so-called "dome gneiss."
2. Schist group.
1. Older gneiss group.

Classification of the gneisses and schists.

A portion of the belt had been previously mapped in detail and briefly described by Mr. F. R. Mallet, who, following the general view then prevalent (1873) as to the approximately proportional correspondence between age and degree of metamorphism, included the gneissose granite (group 3) with the old gneisses (group 1), which differ from the upper and presumably younger schists (group 2) in the possession generally of more felspar and in their more perfect approach mineralogically to unequivocal igneous types. The subdivision of the crystallines into two main groups, one more perfectly gneissose and the other in general schistose, has been recognised in this as in most Archæan areas,

For want of positive evidence to the contrary, and out of courtesy to the old "metamorphic" theory, the former are regarded as older and lower than the schists. With this general arrangement there are no present grounds for disagreement; but we have recently recognised formations mineralogically granitoid and homogeneous, though structurally quite gneissose, whose relations to the "younger" schists are those of intrusive rocks, but whose structures and contact phenomena have been modified by subsequent dynamical metamorphism. Such formations have lately been recognised in the three areas—Coorg, Nellore and Behar—where the younger schists are exposed, and the presence of such a gneissose granite in all three areas helps to complete a parallel in other ways sufficiently striking.

Nature of the "dome gneiss."

The observations recently made in the Behar area confirm Mr. Mallet's conclusion as to the complete absence of unconformable junctions between the schists and gneisses. The gneissose granite ("dome gneiss") crops out, however, at many different horizons amongst the schists, where faulting is not evident, and behaves generally like a rock of exotic origin. Nearly every exposure of this striking rock is surrounded by a zone of variable width, composed of peculiar hornblendic and garnetiferous granulitic rocks, which present characters suggestive of an origin through contact reaction between the intrusive rock and the schists. The persistent way in which these zones envelope every outcrop of the "dome gneiss" is strikingly shown in the area mapped by Mr. Mallet, who, without the aid of the simpler theory more recently adopted, and contrary to what might be expected from the views then prevailing, recorded his observations with a precision and faithfulness difficult to over-praise.

Petrology of the Schist group.

The *Schist group* includes metamorphosed conglomerates, quartzites, crystalline limestones with wollastonite, chondrodite and tourmaline, banded garnetiferous and hornblendic granulitic rocks with epidote and allanite, serpentines, epidiorites, altered basic ash and a thick development of mica schists with accessories like talc, andalusite (chiastolite), sillimanite, kyanite, staurolite and the ubiquitous almandine garnet. The whole group is thus very composite in character and includes metamorphosed products of both igneous and sedimentary types, with a trend of foliation parallel to the strike of the constituent beds.

Dislocation breccias and mylonite.

In several places, noticeably east and north-east of the Jha-Jha railway station, there occur abrupt ridges of a *siliceous breccia.* The disposition of these along lines of probable faulting, and the manner in which they are sometimes imitated by mylonised bands formed along unmistakeable dislocation lines, suggests a fault-rock origin, although for thickness and uniformity of composition it is difficult to find a parallel for them amongst known

dislocation-phenomena. The mylonite produced along some fault planes presents a very close imitation of the so-called "trap-shotten" bands of South India, which Mr. Holland, as stated in my last report, also referred to dislocation-phenomena.

The mica-bearing pegmatite.

The *pegmatites* now so largely worked for mica have been intruded into the schist group in the form of sheets and lenses parallel to the foliation, and, less often, as dykes cutting the schist folia obliquely. The origin and relationships of these pegmatites will be discussed in the full report. Their chief constant constituents are muscovite, felspar and quartz, locally varying in relative proportions, in size and in the abundance of included accessory minerals. The following is a list of the minerals, some new to India, which have been recognised in these pegmatites :—

Albite.	Lepidolite.
Amazon stone.	Leucopyrite.
Apatite.	Magnetite.
Automolite.	Moon-stone.
Beryl.	Muscovite.
Biotite.	Orthoclase.
Cassiterite.	Quartz, pink and white.
Columbite.	Tourmaline, red, blue, green and black.
Epidote.	Torbernite.
Fluor-spar.	Triplite.
Garnet.	

Uranium ochre.

Some of the accessories are sufficiently abundant for economic attention: eucopyrite (arsenide of iron) was found in lumps sometimes weighing 20 pounds; triplite (phosphate and fluoride of iron and manganese) forms thick masses, whilst apatite occurred so abundantly in one of the mica mines that 100 lbs. of material, containing 76 per cent. of phosphate of lime, was collected in one day by three boys working over the rubbish as it was thrown away at the pit's mouth. The scarcity of phosphates in India renders this occurrence a subject worth further attention, as the apatite has hitherto been thrown away with the rejected rubbish which forms large heaps near all the mines. Treating it as a bye-product, the only expense involved will be cooly labour in picking over the waste heaps, royalty and transport.

System of Mica mining.

The system of *mica mining* carried on, largely under European management, is of the most wasteful and primitive type possible. In the Bengal area the so-called mines are narrow, irregular holes, following the pegmatite sometimes to depths well over 200 feet. The whole of the materials—mica, rubbish and water—are brought by coolies to the mouth of the hole, which is very often near the

summit of a hill, being the point where, on account of better exposure, the pegmatite outcrop was originally discovered. On account of the accumulation of water, all mining operations are suspended during the monsoon season, and at the close of the rains the process of "forking" a mine occupies several days and sometimes weeks. In the same way, an hour every morning is spent in baling out the water accumulated overnight. With the one exception now being inaugurated at Bendi, there is not a single vertical shaft in the whole mica-mining area of Bengal, not a single drive or cross-cut to show that the miners have appreciated the actual disposition of the pegmatite as normal intrusive sheets, and, notwithstanding the favourably shaped natural contours of the ground, not a single adit for the removal of water. Contrary, too, to the explicit regulations on the subject, no plans of the mines have been prepared to show the disposition of the workings. That mica-mining has yielded large profits under such remarkable circumstances affords strong presumptive evidence of the value of the deposits and of the success which should be expected to attend a more scientific exploitation of the many fine pegmatite sheets hitherto untouched. The memoir now in course of preparation will, it is hoped, be of some service in disseminating information on these points—the principles of prospecting and mining the mineral, as well as of its preparation to meet the market peculiarities. The export statistics show a yearly output of over 10 lakhs-worth of mica, and with careful treatment of the abundant material still available, India should continue easily to hold its place as the first mica-producing country.

Madras Area.

Petrographical types in the mica belt.

In many points the mica-bearing areas in the Nellore district repeat the essential geological features noticed in Bengal—a crystalline complex of well foliated mica and hornblende-schists, quartzites, sometimes talcose, chloritic garnetiferous and kyanitic, invaded by coarse acid pegmatites, and associated with more perfectly gneissose types as well as a gneissose hornblendic granite. On the east (east of Long. 80°) these crystalline rocks are covered by strata of comparatively recent origin, and on the west they are again hidden by the Cuddapah system forming the Veligondas. Other rocks of interest which have been found within this area are the diabase and olivine-diabase dykes which are abundant near Rápúr; quartz porphyry in the neighbourhood of Gilakapad and a siliceous breccia not unlike the rock found so remarkably developed in the Monghyr district.

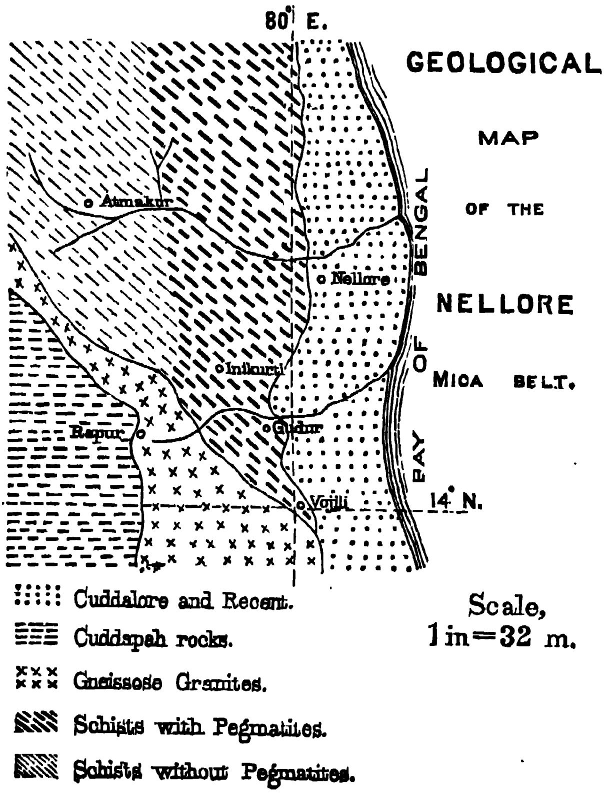
Pegmatites.

The *pegmatite* masses are in the form of intrusive sheets, following the foliation more frequently than as dykes cutting the folia. They are most abundant in the eastern part of the schist area where the foliation planes are inclined at high angles.

The selvages of the masses are generally richer in mica than the central portions.

System of Mica Mining.

Because of the method of working in open quarries with natural slopes on the sides, the mining for mica in the larger pegmatite lenses and stocks remains profitable for a longer period than the mining of the narrower sheets, where, for the same expense in actual quarry work, a much smaller quantity of marketable material is obtained. Practically, all the work carried on in the Nellore district is of the open quarry kind, and although it is one degree in advance of the Bengal methods, it is remarkable that none of the miners have attempted to deal with the pegmatite veins by vertical hauling shafts and drives after the fashion pursued in all modern methods of mining for minerals occurring in regular veins or sheets.



The muscovite obtained in the Nellore district varies greatly in colour, white, smoky, grass-green and yellowish green being obtained both clear and spotted. The ruby-tinted mica, which has made Bengal famous in the market, is not found in Madras, although larger crystals have been obtained

in the latter area. Besides the large numbers of veins covered by laterite and alluvium, there are many places exhibiting favourable indications of mica, which have not yet been carefully prospected.

2. Coal.

Coal in Bikanir.

Mr. T. H. D. LaTouche had already in 1896 reported on a coal seam which was discovered in an old well near the village of Palana in the Bikanir State, and in Records, Vol. XXX, page 122, he has given a description of the seam as it was then accessible. He has since revisited the locality, and gives a few additional facts about this coal in the annexed report.

During my last tour in Rájputána I paid a flying visit to this spot in company with Mr. LaTouche, and was much impressed with the possibilities which this coal discovery suggests and the seeming indifference of the local authorities with regard to it. It is true that the coal is of an inferior quality as compared with Bengal coal, but so is the Quetta and Dandot coal, and yet the latter coal-fields are of very great economic importance to the North Western Railway system, near which no better coal is obtainable except at very high prices.

The coal-field or fields of Bikanir are probably of very large extent, for similar outcrops of coal-seams have been met with in several wells at far distant points. It is, therefore, very strange that three years have been allowed to elapse before a complete exploration of the fields has even been suggested. The country is only slightly undulating, mostly covered with blown sand, and the strata are apparently quite flat or nearly so, so the problem which presents itself is not a difficult one. With the seams so near the surface (little over 200 feet below) a series of drills would cost but little.

There is even a possibility that better seams may be met with below the Palana seam, and I would therefore suggest to drill to at least 1,000 feet near Palana itself, and not only test the upper seam, but explore the beds below, and so obtain a geological key section, which is not obtainable otherwise, there being nothing but recent beds *in situ* for miles around. A series of drills to lesser depths judiciously placed would prove the coal-field and give the available amount of fuel accurately. Before doing this it is folly to incur expenditure for machinery, branch lines of railway or in sinking and furnishing hauling shafts, when nothing definite is known of the extent or character of the field. And yet I believe some of these measures have actually been sanctioned, when an expenditure of R50,000 or less might have given all the information needed. If the coal-field is extensive, as I believe it will turn out to be, it will convert the Bikanir State into the most important of that group of Native States; it lies midway between the North-Western Provinces and Karachi!

The following notes have been sent in by Mr. LaTouche :—

MR. LATOUCHE on the Bikanir Coal.

Since the date of my last visit to Palana in November 1897 the old well which was being cleared out by Mr. Gabbett has been carried down to a depth of 240 feet, at which depth coal was found. The seam here, however, proved to be only 20 inches thick, and as it was not found to increase in thickness in two short headings that were started from the bottom of the shaft, it was decided to acquire from the villagers the well in which the coal was originally discovered (described by me in Records, G. S. I., Vol. XXX, Pt. 3) and to drive headings into the coal in several directions, as I recommended in the report cited. It was found that at the point at which this well was sunk there was a considerable difference in the thickness of coal seen in the sides of the well. On the south and west sides it was about 8 feet, but quickly thickened to 20 feet, at which thickness it remains so far as the headings have been driven up to the present. On the other sides the coal is cut off by what appears to be either a fault or a sloping surface due to denudation of the coal previous to the deposition of the overlying rocks. I am inclined to think that it is not a fault, for the plane of division does not cut directly across the seam, but quickly curves round to the north-east. A heading is now being driven in an easterly direction to prove the extent and nature of this obstruction to the continuity of the seam.

Towards the south, a heading has been driven for a distance of 170 feet, still in coal 20 feet thick, and cross-headings are being laid off from this, which will in a short time be connected with the shaft, so as to provide for ventilation. Mr. Jackson, the overseer in charge of the mine, also proposes to sink a new shaft some 150 yards from well No. 3, to be used as a winding shaft, as the walls of the well are by no means in a safe condition, being merely coated with cement. This well could then be used as a ventilating shaft and also for drawing water.

It seems sufficiently evident from the work that has already been done, that the seam varies considerably in thickness. expanding from only 20 inches in one shaft to a thickness of 20 feet in another only 1,600 feet away. It will therefore be necessary to actually prove the coal by borings before forming any estimate of the amount available.

Now that the coal has been opened out, it is possible to form a more exact opinion as to its quality than was possible from the more or less weathered fragments originally obtained from the sides of the well, and I am sending down a sample of about a maund in weight in order that a thorough examination of it may be made in the laboratory. In appearance it is much more like the brown woody-looking cretaceous coal of the Garo Hills in Assam than any of the nummulitic coals I am acquainted with, and it contains an even larger amount of the fossil resin which is characteristic of the

cretaceous coals of Assam. In the mine at Palana regular layers of this resin can be seen running for considerable distances through the coal, and large nests of the same substance are freely scattered through it.

About 50 tons of the coal has been sent to Mr. Home, Manager of the Jodhpur-Bikanir Railway at Jodhpur, for trial in locomotives, but Mr. Home told me that he found it necessary to get special fire-bars fitted before carrying out the trials, and that the consumption under present conditions in stationary engines was from twice to two-and-a-half times that of Bengal coal in order to obtain equivalent results. This is owing to the rapidity with which the Bikanir coal burns, but no doubt the consumption will be considerably reduced with experience in stoking. Even if it is found unsuited for locomotives, a large demand for the coal will probably grow up in Bikanir itself, where fuel of all kinds is exceedingly expensive.

Borings in the Rampur Coal-field.

In connection with the deep drills for coal which are being made near the Eeb bridge of the Bengal-Nagpur Railway, Mr. F. H. Smith was sent to the Rampur coal-field from the 1st to 8th October 1898, the Government having called for a special report on the sequence and structure of the strata which make up the coal-bearing Gondwanas of that field, with a view of deciding on the best sites for a deep drill which Messrs. Kilburn & Co. had contracted to undertake. Mr. Smith has sent in a report on the locality with map and sections.

3. LANDSLIP AT NAINI TAL.

MR. C. S. MIDDLEMISS.

A very serious landslip occurred at Naini Tal on the 17th August 1898, and Mr. Middlemiss was at once deputed to examine it, and he has since sent in a fully illustrated report on the same, of which the following is an outline :—The slip occurred on the south-west side of the Kalekhan hill, from where a large mass fell into the Ballia ravine above the Brewery, overwhelming part of its buildings and causing a loss of 27 lives, among whom was Mr. Beechey, Assistant at the Brewery; the slip did also much damage to the bridle road, toll house, etc. From the top of the slip to the bottom of the *débris* near the Brewery is about 1,000 feet, while the area affected, including the broken-away scarp, the slope of movement and the deposited *débris*, is about ⅛th of a square mile.

The rock composing the hill-side is a very much shattered slate, in places grey in colour, but chiefly black and carbonaceous, with minute iron pyrites crystals. It has been shattered *in situ* by crushing along fault planes and shear planes. Access of water, owing to the general dip being down-hill, has further rendered the slate rotten, so that in places it is nothing more than a black mud. Under these conditions, and with a heavy rainfall of nearly

40 inches the week preceding the slip, the semi-liquid mass of shales descended from the completely disintegrated and water-saturated slopes.

The general slope of the hill before the slip was not great. The angle formed by a line from the Brewery to the top of the slip is only 20°, whilst the present concave surface of the slip is placed at an angle of 45° to 48° at the top where the rock is broken away: at 35° to 37° along the main slope; whilst the latter lessens down to 10° in the lower part near the Ballia ravine. Three temporary lakes were formed which have since percolated away.

The gist of the precautions recommended by Mr. Middlemiss consists in theodolite observations, which should be carried out in the same manner as on the Sher-ka-Danda slopes within Naini Tal station, by which means early symptoms of any movement of the free edges of the slip may be detected.

4. Irrigation.

Proposed dam in the Chitaldroog District.

From the 5th to the 14th June last Mr. T. H. Holland, with the permission of the Government of India, sat on a committee with Colonel McNeil Campbell, R.E., Mr. G. T. Walch and Dr. J. W. Evans, appointed by the Mysore Durbar to report on the foundations of a proposed dam at Marikanave in the Chitaldroog district. The report, drawn up in consultation with the State Geologist, was communicated direct to the Durbar.

Irrigation Lake in the Bhavani Valley.

From the 6th to the 14th of December last Mr. T. H. Holland was engaged in company with Messrs. Hughes and DeWinton, Chief Engineers, and Mr. Larminie, Superintending Engineer, in examining the sites proposed for a large irrigation lake in the Bhavani Valley. A report on the geological features of the area, with map, has been forwarded to the Madras Government.

B. Geological Surveys.

1. Central Provinces.

Raipur district, Kanker and Bustar States.
Mr. P. N. Bose.

During the last cold weather season Mr. Bose continued the survey of the southern parts of the Raipur district with the adjoining Native States. He has sent in the following notes on the progress of the work:—

Area examined.

'The area examined includes a portion of Dhamtari tahsil (Raipur district), and parts of Kanker and Bustar States—about 2,100 square miles. The country (except a very small portion bordering the Mahanadi near Dhamtari and Kanker) is covered with jungle and very sparsely populated.'

The Gneissic rocks.

'The Kanker-Sihawa country, as well as the northern portion of Bustar territory south of Kanker, is formed almost exclusively of massive granitoid rocks. Gneissic rocks

with usually distinct foliation come in near Bhanwera (22 miles west of Kanker) and extend south towards Antagar and Kolur (Bustar State). Near Bhanwera the strike of foliation is nearly north-west—south-east In the vicinity of Antagar and Kolur, the dominant trend of the strike is north-north-west—south-south-east; and at Rajarao Ghat (between Kolur and Narainpur) it is east-south-east—west-north-west.

The transitions.

Rocks referable to the transition system were encountered towards the end of the season in the southernmost portion of the the area surveyed—south of Antagar, Bustar State—where they form an almost unpopulated, extensive hilly tract. The principal rocks met with in the Bustar sub-metamorphic system this season are hæmatitic and other quartzites, and hornblendic and micaceous schists, the quartzites being found at the base.

The laminated hæmatitic quartzite is the most prominent rock, though its thickness compared to the other members of the system is not great. It gives character and definition to the sub-metamorphic hills, whether forming conical peaks as on Bivapal hill, or bare, sharp, notched perpendicular cliffs as west and south of Kolur.

The sub-metamorphic strata have undergone great disturbance. The dips are high, nowhere less than 45° and often above 60°. At places, as near Bivapal, the strata are folded, contorted and faulted. It should be noted in this connection, however, that the laminæ of the hæmatitic quartzite sometimes simulate the appearance of contortion and crumpling. The strike is often twisted about. It changes from nearly north—south between Bivapal and Kolur to north-east—south-west S. of Kolur, and again to east-south-east—west-north-west at Rajarao Ghat.

The relation to the gneiss is one of unconformability. The unconformability is far from apparent in some sections, in which the gneiss presents the appearance of having been tilted up with the super-incumbent sub-metamorphics, there being hardly any discordance in dip or strike between the two sets of rocks close to the line of junction; and there are obscure transitional passages from the one to the other. Even within the small area examined this season, however, the transitions have been found to rest upon a much denuded surface of the gneissic rocks.

The resemblance of the Bustar transitions to the Dharwars is notable except that I did not find any conglomerates among them. But the area examined this season compared to what, I expect, they will be found to cover is insignificant, and conglomerates may yet be found.

The Chhattisgar Lower Vindhyans. Chandarpur sandstones.

The basal sandstones of the Chhattisgar lower Vindhyans (Chandarpur sandstones) form a belt of well-wooded undulating upland some 10 miles broad along the southern border of the Chhattisgar plain. They were also met with in the northern portion of the Bustar State west of Singenpur and

Keskal. Small outliers of the sandstones occur between these two main areas, and it is possible that they were originally connected. The bottom beds are, as a rule, very thick and conglomeratic or breccio-conglomeratic; at places they consist partly of arkose. They rest upon a denuded surface of the granitoid rocks and are overlaid by coarse, usually greyish or whitish sandstones. Interbedded with them, apparently as lenticular bands, occur, as at Jogtara and Murkatola, laminated whitish and yellowish shales. At places, as west of Singenpur and Keskal, they appeared to be horizontal. Elsewhere, they roll about; and in the Ghat section, south of Murkatola (on the new Dhamtari-Kanker road), a distinct dip was noticed pointing north-north-east, that is, towards the plain.

The Raipur shales and limestones.

The shales and limestones of the plain country are separated from the Chandarpur sandstones by a long stretch of alluvium bordering the Mahanadi. The nearest outcrop met with—calcareous shales at Chundmundia near Kuned—is some 8 miles distant. I must say, however, that the plain country was done by rapid marches, and that closer search may reveal nearer outcrops. The shales just mentioned have the appearance of horizontality. But close to the old Raipur-Dhamtari road, in a stream between Singdelie and Joraturria, some laminated sandy shales were met with which were found to dip 5° north-north-east, that is, in the same direction as the sandstones south of Murkatola.

Economic Geology: Iron.

The iron-ores (limonite and hæmatite) met with occur chiefly in Antagar tahsil, Bustar State. They are more or less superficial, but very rich and extensive. At present, they are but little utilised. The principal seat of the iron industry is at Topal (near Antagar), where I found eight primitive furnaces at work. The iron-ores are of various origins. At Topal, they appeared to me to be the product of decomposition and alteration *in situ* of a very hard, compact, darkish dioritic-looking rock. Near Hurteli, they have been apparently formed by the lateritisation of schistose quartzites. The hæmatite of the hæmatitic quartzite generally becomes concentrated towards the surface, the quartzite being sometimes almost entirely replaced by it; and rich nodules of hæmatite occur in abundance at the foot of the hæmatite-quartzite hills and in the beds of streams flowing therefrom.

Gold.

Gold is washed for in the Kolar river by two families of gold-washers (Sanjhars) settled at Kolur, who extend their operations, however, as far as Sonpur (17 miles south of Kolur) and Portabpur (27 miles west of Kolur), but they do not seem to earn more than one or two annas a day at it. The Kolur river and its feeders drain both the sub-metamorphics and gneiss areas, but evidence seems to point to the sub-metamorphics as the likely source of the gold.

The Chandarpur sandstones yield good building stones at places. The whitish shales associated with them at Murkatola are at present largely used in the neighbourhood as a substitute for lime for white-washing houses. They are, however, pure enough to be usable for pottery purposes.

Building stones, etc.

The survey of the southern portion of what is known in Indian geology as the Chhattisgarh basin was continued by Mr. Smith. It forms the western extension of the geological surveys carried out by that officer during the previous season, and with it the Chhattisgarh basin may now be considered as completed, as far as the geological mapping is concerned. Mr. Smith reports briefly as follows:—

Parts of the Sambalpur and Raipur districts. MR. F. H. SMITH.

The tract of country surveyed this season lies to the east of Raipur, being bounded on the west and north by the Mahanadi River, on the east roughly by longitude 83°, and on the south by latitude 20° 30′. It comprises an area of some 5,000 square miles.

Area.

The Mahanadi River traverses the eastern edge of the Chhattisgarh plain, skirting continuously the marginal hill-range which slopes up gently from the plain southwards and eastwards, forming the rim of the Chhattisgarh geological basin. The southern and eastern faces of these hills are scarped, and they overlook an expanse of broken and hilly country formed chiefly of gneissic and granitic rocks.

General features and geology.

The Chhattisgarh plain is formed of a great series of calcareous beds, shales and limestones, almost horizontal, overlying a quite distinct series of siliceous beds, shales, sandstones and grits, the up-turned edges of which form the marginal hills.

The siliceous series rests on the original uneven surface of the crystalline rocks, usually coarse granites with little or no foliation.

Towards the northern end of the area, in the Sonakan hills, an interesting mass of transition rocks occurs, of intermediate age between the siliceous series and the crystallines. These rocks have been folded and crushed into the crystallines, where they exhibit vertical bedding and are capped by the almost horizontal siliceous series.

The Sonakan beds and the gneiss are seamed with dykes of eurite, compact andesite, diorite and diabase, and also with occasional long veins of brecciated pink and greenish quartz and jaspar.

Drs. King[1] and Ball[2] have classed the calcareous and siliceous series of this basin as upper and lower members of the lower Vindhyan system, which has here attained a much

Correlation.

[1] Rec. Geol. Sur. Ind., Vol. XVIII, pt. 4, p. 169.

[2] Rec. Geol. Sur. Ind., Vol. X, pt. 4, p. 167.

greater development than in the typical Vindhyan area to the north. There does not seem to be any valid reason to differ from this correlation.

On the other hand, in the Chhattisgarh area, we have a set of extremely crushed and metamorphosed transition beds folded into the gneiss, which resemble the Dharwars of the south much more strongly than the less disturbed transition systems of the north.

On the up-turned edges of the Sonakan beds rest, more or less horizontally, the siliceous series of alternating shales and quartzites, overlaid by the calcareous series of shales and limestones. Many rocks of the latter series are indistinguishable from those of the Karnul series of the south.

This sequence of beds has a strong resemblance to that of the south, where the crushed Dharwars are unconformably overlaid by the siliceous Cuddapahs and the calcareous Karnuls, and the suggestion arises that the lower Vindhyan system undergoes a gradual but constant development southwards, until it comprises the whole series of the Cuddapahs and Karnuls. Unfortunately no trace of fossil evidence has yet been discovered.

Crystalline rocks.

About half the area surveyed is covered by crystalline rocks. Those of the western and northern portion are almost entirely coarse porphyritic granites, which pass locally into syenite by the loss of their free quartz. The usual constituents are pink, white and greenish felspars and quartz with small ragged crystals of hornblende and brown mica; veins of epidote are also frequent. Occasional bands of fine-grained rock occur, of the same composition, and in them, and also occasionally in the coarse rock, foliation is seen, with a very general vertical dip and north-westerly strike. To the north-east of the area grey fine-grained gneiss is overlaid by a tongue of the lower Vindhyans running south-westwards. To the north-west it rests normally on the gneiss, but along the south-eastern boundary the Vindhyans are folded and faulted down abruptly into the gneiss. This disturbance extends southwards to the Gandamardan range, which runs parallel to this fault. It is composed of crushed garnetiferous gneiss and quartz-garnet schist, with very strong north-easterly foliation. The different varieties of gneiss, however, pass into one another gradually, and it is impossible to draw any hard and fast line between even the schistose gneisses and the coarse porphyritic granites that may have been intrusive in them.

Sonakan beds.

From the description given by Drs. King and Ball, it is practically certain that the Sonakan transitions form an out-lier of King's "chilpi-ghat" beds, which again are probably continuous with Ball's "sakoli" beds, the lithological characters of all three being almost exactly similar.

The Sonakan beds occupy a patch of irregular hilly country, some 20 miles square. Southwards they branch into several fingers which run out into

the surrounding gneiss. Northwards their upturned edges pass under the horizontal Vindhyans.

It seems impossible to make out any definite sequence in these beds. They are all vertical, but there is no plain evidence of any symmetrical folding. The crushing and the intrusion of numerous trap-dykes have produced intense metamorphism in places, and the rocks vary from soft clay-slates and argillites to compact siliceous hornstones, petrosilex, and fine amygdaloidal felsites with bands of conglomerate and boulder beds, and local subordinate bands of quartz-magnetite schist.

Three main north and south hill ranges are formed of compact felsites frequently full of white grains of quartz, felspar and occasionally calcite. They seem to pass into extremely fine and silky hornblende schists. The intermediate valleys are filled with the softer clay slates, with occasional bands of quartz schist and veins of quartz. The boulder beds consist of compact siliceous and trappean rock, through which are scattered boulders, up to 2 feet in diameter, of all kinds of gniess, granite, syenite, diorite and serpentine, with pebbles of jaspar, flint and banded hornstone. In places the crushing has been so great that the pebbles are drawn out into lenticular masses of crushed fragments.

Much interbedded trap occurs amongst the Sonakan beds, bands of compact andesite running frequently along the strike. Dioritic dykes are also common, but they have intruded subsequently and irregularly on the gneiss and the transition beds alike.

Another small patch of metamorphosed rocks, folded into the gneiss, occurs to the south-east. They consist of earthy mica schists, with white quartz veins running irregularly through them, but they bear no resemblance to any of the Sonakan beds.

Lower Vindhyans.

Siliceous series.

Overlooking and resting upon the gneiss and transitions comes the siliceous band of the lower Vindhyans, forming the marginal hill range which slopes down gently to the Chhattisgarh plain. Its thickness, which 40 miles to the eastward reaches 5,000 feet, has here dwindled down to less than 200 feet.

To the north, the siliceous series consists of an upper band of fine purplish sandstone, with numerous green chloritic grains, overlying a band of pink to buff clay shales, which again overlies a band of coarser felspathic sandstone and grit. Southwards, however, the two upper bands thin out and disappear, while the lower band increases in thickness, being composed of white quartzitic sandstone above, passing down into a pink highly felspathic grit or arkose. The total thickness of the series remains much the same throughout, being from 150 to 200 feet. The beds of the siliceous series dip down very gently, with apparent conformity below the calcareous series of the plain.

The Chhattisgarh plain presents a perfectly flat surface, on which, here and there, different varieties of almost horizontal limestone crop out. Continuous sections are very rare, and so any determination of the detailed sequence of beds must be unsatisfactory.

Calcareous series.

The chief rocks of the series are calcareous shales, porcellanic flags and limestones. The general section seems to be as follows, in ascending order :—

Above the siliceous series come several hundred feet of grey compact flags. Above these a rather greater thickness of soft purple shales, with pale grey-green laminæ. These are overlaid by a curious band of purplish, nodular, shaly limestone, traversed by numerous irregular vertical cylinders of purer limestone, due apparently to concretionary action. Above this, in the Raipur neighbourhood, bluish compact limestone appears, overlaid by red sandy shales, which are much folded locally. The latter appear to be the uppermost beds met with.

Minerals of economic value, with the exception of laterite, limestone and building stone, appear to be absent. The Sonakan neighbourhood is said to yield gold, and an English company worked there for some years, but found nothing. I could not find any trace of gold either in the stream beds, or in the quartz reefs and bands of grit and conglomerate in the lower Vindhyans.

Economic geology.

2. Central India.

The geological survey of South Rewa, which had been carried on during several previous years under the superintendence of Mr. Oldham, required some overhauling and completion in parts, which this officer was charged with during the last cold weather season. In addition, a part of the lower Vindhyan area in Mirzapur was examined, as it was hoped that some additional information would be obtained regarding the relation of the lower to the upper Vindhyans. He has suggested an interpretation of the geology of the country south and west of Markundi—where the exposures of rock are few and far between—which is simpler than that suggested in the Memoirs, Vol. VII, Pt. I. The most interesting result, however, has been the discovery of an intrusion in the Lower Vindhyans; the rock is extremely decomposed, too much so to be determined, but has the appearance of having been originally a leucite rock. At Markundi the lower Vindhyan limestone was found to be traversed with veins of sandstone having the appearence and behaviour of intrusive dykes.

South Rewa.
MR. R. D. OLDHAM.

The survey may now be considered as finished and presents a very interesting portion of detailed work, sufficiently complete in itself to deserve special description; the observations made by Messrs. Oldham, Datta, Smith, Vredenburg and Grimes will be embodied in a detailed report by the

first named gentleman and will be published in a "Memoir" at an early date.

3. WESTERN RAJPUTANA: JODHPUR.

Surveys have been carried on intermittently in the Aravallis and the adjoining areas in past years, and the greater part of the Rajputana States have been at least geologically reconnoitred, but much remains to be done to link the surveys to those of the adjoining parts of India. Nevertheless, I consider that the surveys which Mr. LaTouche has completed during this last field season should, for a time at least, suffice, other portions of the Indian Empire having greater claim to consideration. This year's work embraces the greater portion of the Jodhpur State, and with the previous two years' work in Rajputana presents a rounded off area which Mr. LaTouche will describe in a detailed report. Herewith annexed is his report on this year's work.

MR. T. H. D. LA TOUCHE, *on Western Rajputana.*

Barmer District.—The greater portion of the rocky hills which protrude through the sands of the desert to the west of Barmer (Lat. 25° 45′ N., Long. 71° 26′ E.) are formed of the Malani volcanic rocks. These do not present so great a variety as those occurring on the eastern side of the desert about Jodhpur and Siwana, but consist for the most part of compact dark grey, sometimes black, glassy or pitchstone-like lavas, containing scattered phenocrysts of white or pink felspar and grains of quartz. Flow structure is frequently met with amongst them, and some of the flows are highly spherulitic. A reddish-brown, more strongly porphyritic, lava is found in places, especially in the neighbourhood of Barmer itself. There are no beds of tuff intercalated with the lava flows, but in one locality, near the village of Jesai, about 10 miles west of Barmer, a thick bed of conglomerate, consisting of well rolled pebbles of the lavas imbedded in an ashy matrix, is interstratified with them. The bedding of this is inclined to west-south-west at an angle of 30°, but with this exception owing to the similarity of the lavas forming the various flows, it is difficult and often impossible to make out any bedding among them and to determine what amount, if any, of disturbance they have undergone since they were poured out. They seem to have been protruded from a network of fissures, and to have been heaped together without any definite arrangement. No trace of anything like a vent is to be seen anywhere.

At several places, *viz.*, the hills at Jesai, Taratra Chotan and Radhana, a coarsely crystalline hornblendic granite, without mica, is associated with the volcanic series. The relations of this rock to the lavas are not so clearly defined as they are in the Siwana and Jalor districts, described by me in previous reports. Occasionally veins may be observed proceeding from the granite into the surrounding lavas, but in other instances, notably in the hill at Rudhana, 27 miles west by north from Barmer, the granite is traversed by

broad east and west dykes of a dark coloured eurite indistinguishable from the lavas. It appears as though the granite had been intruded into the lavas in the form of bosses or laccolites, after a considerable portion of the lavas had been poured out, and that they were subsequently broken through by a fresh emission of lava. None of these dykes are seen in actual contact with any of the surface flows of lava, and it seems doubtful whether any of them reached the surface.

Both the granite and lavas are broken through by large dykes of basic rock (diorites) which generally run about east-north-east—west-south-west. The granite thus appears to be older than the Siwana granite, which, so far as I have seen, is never traversed by basic dykes.

Barmer Sandstones.—At the town of Barmer sandstones and conglomerates are exposed resting unconformably upon the volcanic rocks, with a dip of about 15 or 20 degrees to north-east. Their thickness may amount to about 150 feet, but the top is concealed by sand, and there are no wells near the edge of the hills from which any idea of the rocks overlying them might be obtained. The sandstones contain numerous plant remains, but usually in too fragmentary a condition for identification. Some of them are undoubtedly fragments of dicotyledonous leaves. Mr. Blanford supposed the sandstones to be of jurassic age and to correspond to the Lathi group, which also contains fossilised wood, of Jaisulmer. The pebbles in the conglomerates are well rolled, and consist almost entirely of fragments of the lavas. The sandstones occur again in an isolated hill (997 feet) near Lunu, 5½ miles north-west of Barmer, where they dip at an angle of 26° to north-east against a ridge of Malani lava which runs through the centre of the hill, and patches appear among the sandhills about 12 miles further north, near the villages of Borithia and Sondri. The base of these is not seen, and I could discover no fossils in them.

On the eastern side of the desert, near the banks of the Luni river, several isolated patches of rock appear from beneath the sandhills. Sandstones similar to those at Barmer occur near the village of Naosir (Lat. 25°47′ N., Long. 71°55′ E.) and about 8 or 10 miles to the south-west near Sanpa and Sarnu. At the former place their junction with the underlying rocks is concealed, but near Sanpa they are seen to rest upon a very uneven platform of Malani lavas. The sandstones have a slight easterly dip. I could find no trace of fossils in these rocks, but they are lithologically exactly similar to the Barmer sandstones.

Shergarh District.—A considerable area to the west and north-west of Jodhpur has also been mapped this season. The rocks met with are sandstones similar to those at Jodhpur, forming low scarped hills resting horizontally upon a slightly undulating platform of Malani lavas. They extend for about 46 miles from Jodhpur to the neighbourhood of Shergarh, where

they disappear beneath the sandhills. Near the village of Osia (Lat. 26°44′ N., Long. 72°58′ E.) the sandstones contain impressions which may be of organic origin. They consist of slightly raised, straight or curved markings, which are only discernible when the surface on which they occur is held obliquely in a strong light. The surface of the sandstones has a smooth glazed appearance as though it had been exposed to considerable pressure, and it is not certain whether such impressions could not be caused by mechanical means. Specimens have been forwarded to Calcutta for examination. The exact horizon of these markings is doubtful, since the base of the sandstones is not exposed anywhere in the neighbourhood of Osia, but judging from the general inclination of the beds, the sandstones at Osia probably belong to a higher horizon than any of those exposed near Jodhpur.

Godwar District.—Towards the close of the season I paid a short visit to the district of Godwar, to the south-east of Jodhpur, for the purpose of examining the relations of the rocks of the plains to those of the Aravallies, and of investigating one or two mineral discoveries which have recently been made in that direction. The greater portion of the plain of Godwar is occupied by an exceedingly coarse granite, which was apparently intruded into the Aravalli schists before the disturbance of the latter and has been folded up with them. The main boundary of the granite with the schists occurs along the foot of the range, and has apparently determined the position of the scarp. Large patches of the schists, however, occur for a considerable distance to the west of the scarp surrounded as a rule by granite. Near the village of Desuri (Lat. 25°16′ N., Long. 73°37′ E.) one of these patches, consisting of calcareous schists, in actual contact with the granite, has been converted into a white saccharoid marble, resembling the well known marble of Makrana, which is quarried for building purposes. A lenticular fissure containing large rhombohedral crystals of calcite or Iceland spar, was recently discovered among the hills to the south-east of Sadri, some miles to the south-west of Desuri. Some of the crystals are fairly transparent, but none are without flaws, and the bulk of them are so opaque as to be of no value.

A find of copper and gold was reported by Captain Hughes of the Erinpura Irregular Force near the village of Rohera, a station on the Rajputana-Malwa Railway in Sirohi territory. The place had evidently been worked for copper in ancient times, and to a considerable extent, as may be seen from the heaps of copper slag in the vicinity. The old mine has been filled with *débris* and was not excavated to a sufficient depth at the time of my visit to enable me to judge of the extent of the deposit. The gold occurs in a pyritous schist associated with the copper-bearing schist, but does not appear to exist in workable quantity.

4. HIMALAYAS : SPITI.

After many years' intermission, the geological survey of the higher ranges of the Himálayas has been resumed. My own reconnaissance of Spiti, which I made at the end of the rains of 1883, has been of an incomplete nature and has only covered the southern portion of the area. Since then Professor Dr. Diener has described the fossils found in Spiti by myself and others, to which the late Dr. Stoliczka had contributed a large share Spiti is classic ground for Himálayan geology, and it is therefore fitting that the continuation of research amongst the higher ranges of this mountain system should start from there.

Accordingly, Mr. H. H. Hayden received instructions in May 1898 to proceed to Spiti to make detailed studies in the region of the upper Pin valley and adjoining areas, to correct not only some points in the geological survey of it, but also to make exhaustive collections of fossils. His deputation proved a great success; he acquired fine collections of almost all the beds between the cambrian and the upper trias. His discovery of *trilobites* in the lowest silurian beds is of great importance, especially so, as hitherto the lower palæozoic rocks in the Himálayan area have been found poorest in fossil remains.

The lower trias and muschelkalk have yielded a very fine series of fossils amongst which are a fair number of new species. Dr. Krafft has determined the triassic fossils, and his remarks on the same are published on pages 11 to 22 of this report.

Mr. Hayden reports as follows :—

H. H. HAYDEN'S *report on Spiti.*

The geology of Spiti has already been touched upon by various writers, the most important work being that of Dr. Stoliczka (Mem. G. S. I., Vol. V) and of Mr. Griesbach (Mem.G. S. I. Vol. XXIII). The past season's work has enabled me to add a few facts to those already known.

PALÆOZOIC GROUP.

Palæozoic group. Two facies.

As stated by Stoliczka,[1] the palæozoic rocks of Spiti show two distinct facies, which for convenience of description he has named the "southern" and the "eastern."

The southern facies is seen in the valleys of the Pin, Parahio and Ratang rivers, while the eastern is found throughout the lower reaches of the Spiti Valley below Po. The junction between these two series must lie somewhere between the Thanam valley and Shalkar in Bashahr, and this I hope to be able to work out during the coming camping season. Until the exact relations which these two facies bear to one another have been determined it will be necessary to describe them separately.

[1] Mem. G. S. I., Vol. V, p. 16.

Southern facies.

Haimantas.

The haimantas have been divided by Mr. Griesbach into three sub-divisions,—lower, middle and upper. To his descriptions of the two former I have nothing new to add.

The upper haimantas he has defined as "two zones of very hard quartz shales,—the lower of which is formed by densely red and pink quartz shales which pass upwards into greenish-grey quartzite and shales with pink shaly partings." The thickness of this series is given as from 250 to 500 feet. In Spiti I find that the upper zone is of considerably greater extent than has been hitherto supposed, the total thickness being about 1,000 feet. It consists of alternating beds of quartzite and slate with occasional narrow bands of hard grey dolomitic limestone. Towards the upper limit of the series the limestones gradually increase in thickness till the system becomes one of limestone.

Silurian.

The slates contain considerable numbers of trilobites, chiefly of the family *Olenidæ*,[1] and include species of *Ptychoparia Corda* and allied forms, with *Dikelocephalus* and *Olenus* in the higher beds. These rocks are therefore probably of upper cambrian age, and consequently the overlying limestone must be classed as lower silurian. I found only fragments of fossils, none of which could be determined. The dolomite is overlain by red slates followed by another bed of dolomite, the upper portion of which is conglomeratic. This passes up gradually through grits into the pinkish-red "upper silurian quartzite," described by Mr. Griesbach. This quartzite is apparently unfossiliferous, but is overlain by a limestone series in which I found large numbers of fossils.

Upper silurian.

The "upper silurian" quartzite, of which the total thickness is probably about 1,500 feet, passes up into reddish siliceous shales, which gradually become marly and eventually give place to calcareous shales and limestone. The lower siliceous members of this series appear to contain no fossils, but in the upper limestones are found large numbers of *brachiopods*, *corals* and *gastropods* (chiefly *pleurotomaria* sp.), while *nautilus* also occurs and one fragment of a *trilobite*. The fossils are unfortunately very badly preserved, but some can be determined. Among the corals are specimens of *Halysites* cf. *H. Escharoides*[2], Lmck., a species occurring at about the middle of the upper silurian beds of Europe. The trilobite fragment is part of a head-shield of *calymene*, and resembles *Calymene blumenbachii*, a typical silurian form. It is, therefore, probable that the age of these limestones is upper silurian, and not devonian as hitherto supposed, and the overlying system, the "red crinoid limestone" of Mr. Griesbach, may prove to be of devonian age.

[1] Beecher: Natural classification of the trilobites. Am. Journ. Science, Ser. IV, Vol. III, p. 181.

[2] I am indebted to Dr. Nœtling for this determination.

Carboniferous.

The southern facies of the carboniferous system has been described by former observers and I have nothing new to add.

Productus shales.

The chief point of interest with regard to the *Productus* shales is the discovery in them of *ammonites*; they occur near the top of the series, at about 30 feet below the base of the *Otoceras* beds, and usually form the centre of hard, cherty concretions, but when extracted are invariably found to be in a state of partial or total disintegration. A few specimens can be determined and include *Xenodiscus carbonarius*, Waagen, species of *Arcestes?* and a form strongly resembling *Cyclolobus Oldhami*, Waagen, which occurs in the upper Productus limestone of Jabi in the Salt Range.

About 10 feet above this ammonite horizon is found a band of hard brownish siliceous limestone full of *orthoceras* sp.

Eastern facies.

In lower Spiti near Po and Thabo the Productus shales are underlain by a thick bed of sandstone containing many fossils, chiefly species of *spirifer* and *athyris*, and passing down into a series of grits and conglomerates with interbedded shales. Near the upper limit of the grits are two fossiliferous bands, the lower of which contains numerous specimens of a large *productus*. Below this band the grits become coarser and eventually pass into typical conglomerates, consisting of water-worn pebbles of quartzite, embedded, as a rule, in a coarse gritty matrix; at times the matrix becomes finer, and the rock, where it has suffered from pressure, might possibly be mistaken for a boulder-slate. It was probably this local deceptive appearance of the conglomerate that led General McMahon to compare it to the Blaini conglomerate of the Simla area.[1]

Anthracolithic system.

This series of coarse beds is underlain by a great thickness of alternating beds of quartzite (at times sandstone) and dark blue to black slates and shales. The series attains an enormous development in the lower Spiti Valley, its total thickness being probably not less than 3,000 feet. Fossils occur in considerable quantity in at least three horizons situated at about 500, 1,000 and 1,500 feet, respectively, below the Productus shales.

The two upper horizons consist of dark slates containing very large numbers of *gorgonia*, *fenestella* and other bryozoa, with badly preserved *brachiopods*. So abundant are the remains of *fenestella* in the uppermost horizon that I have named it the "Fenestella shales."

The third horizon also consists of dark grey and black shales containing inumerous plant remains: these are well exposed near Thabo.

[1] Rec. G. S. I., Vol. xii, p. 63.

The underlying beds are very similar to the upper part of the series, but have suffered considerably from metamorphism, intrusions of basic igneous rock being very common, and the slates are often altered into garnetiferous mica schists.

The chief observers who have previously examined this area are Stoliczka, Theobald, Mallet and McMahon, and hitherto this series has been classed as silurian; but no collections having been made, the identification rested merely on a fancied lithological resemblance to Stoliczka's "Bhabeh" and "Muth" series. The fossils collected, however, during the past season point to a carboniferous and permian age for these beds, the "fenestella shales" being probably the representatives of the Zéwan beds of Kashmir. Till the collections have been examined in greater detail, it will therefore be most convenient to include the whole series of slates and quartzites under the term "anthracolithic system," a term proposed by Professor Waagen and adopted recently by Diener.[1]

Carboniferous.

The anthracolithic beds are underlain by a series of calcareous rocks, well seen near Huling E. G., on the Spiti river, in Hundes.

The uppermost beds consist of marly calcareous shales, passing down into limestones, the upper portion of which is a white to grey crystalline, saccharoid variety, containing locally large quantities of gypsum in the form of nests of large crystals of selenite and also in tufaceous masses.

Below this limestone are more calcareous shales with limestones, underlain by and partially interbedded with white quartzite, which is lithologically similar to the carboniferous white quartzite of Muth.

Fossils occur in the calcareous beds, but they are all badly preserved and cannot be identified. The limestone overlying the white quartzite is usually white or pink and contains large numbers of crinoid stems.

The white quartzite is underlain by a red shaly limestone passing down into a bright Indian-red limestone containing crinoids and strongly resembling the "red crinoid limestone" of the southern series.

? Silurian.

This limestone passes down into a series of sandstones and quartzites, which in their upper portion are interbedded with the red crinoid limestone, and lower down with light grey schistose slates. Impressions of bivalves and remains of corals and crinoids occur on the weathered surfaces of the rocks, but none of the fossils could be determined.

In the absence of other evidence, the lithological similarity of the white quartzite and the red crinoid limestone to the carboniferous rocks of Muth point to a carboniferous age for this series, while the sandstones may represent the upper silurian. The lowest beds here seen consist of about 80 feet of

[1] Anthracolithic fossils of Kashmir and Spiti. Pal. Ind., Ser. XV, Vol. I, Pt. 2.

soft light-grey to green magnesian schist, underlying the upper silurian (?) sandstones: it is considerably metamorphosed and appears to contain no fossils.

MESOZOIC GROUP.

The mesozoic rocks of Spiti have been very fully described by former observers. Some additions have, however, been made to our knowledge of their fauna. An account of these will be found in the paper by Dr. A. von Krafft published with this report

Igneous Rocks.

Basic igneous rocks.

Basic igneous rocks are found near Muth and also at Po and other localities in the lower Spiti Valley. The specimens collected during the past season have not yet been examined in detail, but they consist chiefly of diorites, epidiorites and rocks composed of amphibole and epidote.

Acid rocks.

The acid rocks are represented by the great masses of granite which form many of the higher mountain ranges to the west and south of Spiti.

Economic Geology.

Gypsum.

The occurrence of Gypsum in the lower Spiti Valley near Huling in Hundes has already been described by Mr. Mallet.

Galena.

Galena is found in small quantities near the summit of the range between Po and Dangkhar, where it occurs in the form of small isolated cubes in quartz veins which run through the upper trias shales. The quantity is small and it is of no economic value, although the local natives use it for making bullets.

Iron.

Iron ore in the form of *red hæmatite* occurs as a bed 10 feet in thickness among the lower silurian rocks west of Muth, and large quantities of *yellow ochre* occur in recent deposits near Dauksa E. G. in the valley of the Ratang river.

5. BALUCHISTAN.

Western Mari hills and Zhob Valley.

Dr. Fritz Nœtling was posted to Baluchistan for the summer and autumn months in order to continue survey work in the Western Mari hills and the western portion of the Zhob Valley. He left headquarters on the 21st April and started actual field work on the 14th May at Harnai. During the first weeks he studied the magnificent sequence of strata about Torkhan and Smallan, which range from the upper jurassic to the tertiary system.

The primary object of the work consisted in mapping the blank patches left by Messrs. Oldham and Smith on the maps of that area, and to collect fossils from the five sections exposed there. Later on in the season he marched to Fort Sandeman and from there to Thanishpa in the hills bounding the Zhob Valley on the north. This excursion proved of great importance. When I visited the area in 1894 I had mapped a great thickness of sandstones and shales, often hardly distinguishable lithologically from the Siwaliks, as probably MIOCENE; they rest on undoubted *nummulitic* beds, but the upper beds were poor in fossils. Dr. Nœtling has succeeded in establishing the miocene age of the beds by discovering a rich fauna, amongst which are numerous characteristic species of Dr. Blanford's Gaj beds of Sind.

Dr. Fritz Nœtling's preliminary report.

Dr Nœtling has sent in the following preliminary report on the results of his work in Baluchistan :—

INTRODUCTION.

Mari hills and part of the Zhob Valley.
Dr. Fritz Nœtling.

The surveys may be divided into two parts, *viz.* :

(1) Completing the portions of the sheet No. 116 of the ½ inch map (Loralai) left unsurveyed by previous observers.

(2) Linking up Mr. Griesbach's survey of the Western Zhob with his map of the Takht-i-Sulliman.

Owing to the somewhat unsettled condition of the Mari tribes, the greater part of the first task had to remain unfinished, whilst the scarcity of water and supplies made the second programme very difficult, although it may be claimed that the surveys between the Western Zhob and the Sulliman Range have been successfully joined.

In September I returned to Loralai and Mazár Drík and devoted the remaining part of the field season to the study of the tertiary beds of Harnai, Shahrig and Khóst.

On the way back to Calcutta I made a short excursion to Chidru in the Salt Range, where I continued the study of the beds between the permian Productus limestone and the Ceratite beds on which I report separately.

The sedimentary formations observed may be divided into the following divisions :—

I. Mesozoic group.
  1. Jurassic system.
    Polyphemus limestone.
  2. Cretaceous system.
    A. Lower cretaceous series.
      Neocomian.
    B. Upper cretaceous series.

Kainozoic group.

1. Tertiary system.
   - A. Eocene series.
     - (*a*) Lower Eocene.
       - (*aa*) Etage Pathanian.
       - (*bb*) Etage Ranikotian.
     - (*b*) Upper Eocene.
       - (*aa*) Etage Khirtharian.
   - B. Miocene series.
     - Tanishpa beds.
   - C. Pliocene series.
     - (*a*) Lower Siwaliks.
     - (*b*) Upper Siwaliks.

I. Mesozoic Group.

1. The Jurassic system.

The Jurassic system as represented by the Polyphemus limestone was chiefly observed in the Harnai district and in the Mazár Drick anticlinal. A sub-division of the limestone seems impossible.

Appearances point to the limestone having been eroded before the neocomian beds were deposited.

2. The Cretaceous system.

A. The Lower Cretaceous series.—Deposits belonging to the neocomian are widely distributed in Baluchistan. Their fossil contents amongst which *Belemnites dilatatus* is the most characteristic form have already been described by me in Pal. Ind., Ser. XVI, pt. II.

I may mention here that a mistake has occurred in my memoir, and this was in the description of an interesting fossil as *Gryphæa Oldhami*, said to have been found in the Belemnite shales. But as a matter of fact not only did I not find anything but *Belemnites* in this bed, but the *Gryphæa Oldhami* is one of the characteristic species of the zone of *Gryphæa vesicalaris*, in which I found it in large numbers at Dés, and there is probability that this species has ascended from the neocomian to the top of the cretaceous system.

The upper neocomian seems to be represented by a conspicuous white shaly limestone, which is seen to overlie the belemnite beds, but which so far has proved unfossiliferous.

As far as yet ascertained, the neocomian series is directly overlaid by the Danien, the whole middle cretaceous (Cenomanien, Turonian and Senonien) being absent altogether, or it may be they cannot be recognised without fossils.

B. The Upper Cretaceous Series.—The Dés anticlinal, as exposed on the northern side of the Dés hill, exhibits the most complete section of the upper cretaceous series.

1. Zone of gryphæa vesicularis.

(*a*) *Unfossiliferous Shales.*—The section begins with a series of bluish nodular shales, subdivided by harder layers. No fossils have been discovered in these beds, though I particularly searched for them. A further subdivision of this group is therefore impossible for the present.

(*b*) *Horizon of Nautilus spec. nov.*—The lowest fossiliferous horizon met with and which exhibits the same lithological character as the beds below is a bed of about 2 feet in thickness of an arenaceous shaly limestone of bluish white colour. This limestone is the chief bed of *Sphenodiscus acutodorsatus.* Besides this species, a *nautilus* new to Baluchistan was found, the shell of which was covered with very regular rounded ribs.

(*c*) *Horizon of Spondylus spec nov.*—Then follows the same clay as before and above that a similar layer as the *Sphenodiscus* bed, which, besides numerous specimens of a new species of *Spondylus*, contains the genera *Crioceras Turrilites*, though they are of rare occurrence.

(*d*) *Horizon of Pecten spec. nov.*—Above this bed comes in a series of nodular limestones of yellowish colour, separated by softer layers, which are more or less argillaceous, sometimes also arenaceous, and which it would have been almost impossible to subdivide if they did not contain a rich fauna.

The lowest of the horizons is characterised by the frequent occurrence of a large smooth *Pecten* (not yet described) in which the following species have been recognised:—

Holectypus baluchistanensis.
Clypeolampas helios.
,, *vishnu.*
Hemipneustes pyrenaicus.
Hemiaster Oldhami.
Ostrea ungulata.
Gryphæa vesicularis.
Vola quadricostata.
,, *quinqueangularis.*
Pecten dajurdini.
,, *spec. nov.*
Lima spec. nov.
Nerinea ganesha.
Ovula spec. nov. (gigantea).
Nautilus spec. nov.

(*e*) *Horizon of Hemipneustes compressus.*—Above this succeeds a nodular brown limestone with argillaceous intercalations which yielded the richest fauna discovered; according to a preliminary examination, the following fossils were found :—

Trochosmilia protectans.
Cyclolites regularis.
Cyphosoma sp.
Protechinus paucituberculatus.
Holectypus baluchistanensis.
Pyrina gigantea.
Echinanthus Griesbachi.
Clypeolampas helios.
,, *vishnu.*
Hemipneustes compressus.
,, *leymeriei.*
Hemiaster Blanfordi.
,, *Oldhami.*
Ostrea ungulata.
Exogyra pyrenaica.
Gryphæa vesicularis.
,, *Oldhami.*
Vola quinquangularis.
,, *quadricostata.*
Pecten dajurdini.
Cardita subcomplanata.
Pholadomya indica.
Trochus lartetianus.
Turritella spec. 1.
Nerinea ganesha.
Ovula spec. nov.
Nautilus sublaevigatus.
Sphenodiscus acutodorsatus.

Besides the above, several new species, among which a gigantic *Cucullæa* is of special interest, were discovered. The determination of the Cephalopoda is not quite certain, as it seems to me that the suture-line of the ammonite discovered differs from that of the typical *Sphenodiscus acutodorsatus*; so this point must be settled afterwards; there is certainly another species new to *Balúchistan.*

2. *Zone of Nerita (Natica) d'archiaci.*

(*a*) *Horizon of Pyrina ataxensis.*—Above this horizon is a dark blue unfossiliferous clay, in which towards its upper parts layers of bluish limeston

begin to appear, which increase in number till the argillaceous element has almost disappeared; this is the chief habitat of *Pyrina ataxensis* which may be collected in any number, and it may be remarked that it does not occur in any lower or higher horizon. The following is the list of fossils :—

Protechinus paucituberculatus.
Pyrina ataxensis.
Hemipneustes compressus.
Echinanthus Griesbachi.
Gryphæa vesicularis.
Cucullæa spec. nov.
Nerita d'archiaci.
Nerinea ganesha.
Ovula spec. nov. (*gigantea*)

(*b*) *Horizon of Echinanthus Griesbachi.*—Intimately connected with this horizon, and of the same lithological character though of brownish colour is the horizon of *Echinanthus Griesbachi.* This bed contains, besides the fauna above mentioned (except *Protechinus paucituberculatus*), numbers chiefly of *Echinanthus Griesbachi*, and this series is terminated by (*c*) *Horizon of Natica d'archiaci*, an argillaceous nodular limestone of brown colour full of *Nerita* (*Natica*) *d'archiaci.*

3. Zone of Radiolites Muschketoffi.

Above this bed the lithological facies changes through the appearance of hard dark grey limestone, which however contains nodular layers full of

Radiolites Muschketoffi.
,, *dilatatus.*

But it is very strange how suddenly the Radiolites both appear and disappear. At Mazár Drik I failed to discover the *Radiolites* horizon but though I paid special attention to the matter, in the light of the knowledge of their occurrence at Dés not a trace was found, and I may thus confidently say that the *Radiolites horizon* is not developed at Mazár Drik.

4. Zone of gen. nov. et spec. nov.

The *Radiolites* horizon is succeeded by an olive coloured, perhaps a little darkish green, clay, which seemed at first unfossiliferous, but which was found to contain geodes full of fossils, none of which had come under my examination before. The chief fossils are an interesting new genus, a new *Ostrea* which almost imitates a brachiopod, *Anomia* spec. and a number of other species which have not yet been determined.

(5) *Zone of Indoceras baluchistanense.*

Above this is the red sandstone which is capped by the red clay, and above this occurs a brown clay with strings of limestone. Fragments of *Indoceras baluchistanense* were found, but the best preserved specimen comes from the previous horizon.

(6) *Zone of Ostera acutirostris.*

This horizon gradually passes into a hard dark limestone, weathering a brown colour, which is full of sheils of *Ostrea* spec. But in some softer layers were found well preserved specimens of this species, which, though their identity with the European *Ostrea acutirostris* may perhaps now be questioned exhibit the closest relationship with a species very common in the upper part of the Ghazij (lower eocene). The similarity of both species is so striking, that for the present I fail to discover any difference. But a more searching examination may perhaps reveal the distinguishing characters. *Cardita baluchistanensis*, which is so common at Mazár Drik, is very rare at Dés.

The systematic collection of the fossils has proved the fact, that there exists a remarkable difference between the fauna of the zones 1 and 2 and that of zones 3 to 6. This faunistic difference was at once noticed at Mazár Drik and confirmed at Dés, and though it must be admitted that, taken as a whole, the fauna is of uniform and inseparable character, the differences still exist and justify the subdivision I have adopted below. The main points of this faunistic difference are the following:—

(*a*) Out of the 16 species of *Echinoidea* which I described 13 are restricted to the lower two horizons; only three, *viz.*, *Hemipneustes compressus*, *Hemiaster Blanfordi* and *Echinoconus gigas*, occur in the upper horizons, but the first two also occur in the lower horizons, where there is their principal habitat. They are so extremely rare in the upper horizons that in my collection they are only represented by one specimen each; but on the other hand, it is certain that *Echinoconus gigas* does not occur in the lower beds.

(*b*) Among the Pelecypoda *Gryphæa vesicularis* and the characteristic, costated *Ostrea ungulata* do not ascend to the higher horizons; they are absolutely restricted to the lower ones.

(*c*) In the Gastropoda the representatives of the genera *Ovula*, *Pugnellaria* (=*Pugnellus giganteus*) occur mainly in the upper beds.

(*d*) In the Cephalopoda the true *Sphenodiscus acutodorsatus*, in addition to several evolute genera like *Crioceras*, *Turrilites*, are confined to the lower horizons, while *Indoceras baluchistanense*

is absolutely restricted to the top of the upper beds. This interesting species may be considered one of the youngest, if not the youngest, among the representatives of the family Ammonitidæ.[1]

At Mazár Drik only four species out of a fauna of about 30 species ascend into the higher horizons, and at Dés a similar ratio seems to obtain, though this has not been fully studied yet. Further details cannot be given till the whole fauna has been examined, but the above is sufficient to prove that there is a considerable difference in the composition of the fauna of the lower and upper beds and this may be expressed as follows:—

In the lower beds species prevail which are of a more archaic type, and these species die out in the upper beds, where more modern types appear.

The conclusions with regard to the age of the upper cretaceous beds, which I had arrived at in my memoir, were *solely* based on species occurring in the *lower* horizons. The age deduced from these species therefore applies in particular to the lower horizons, which must therefore be correlated with the etage *maëstrichtien*; it having however been pointed out that there exists a considerable difference in the composition of the fauna of the lower and upper horizons, it is unquestionable that the fauna of the upper beds must be regarded as belonging to the upper part of the Danien, *viz.*, the etage *Garumnien.*

The question arises as to the boundary between these two groups, and this question is by no means an easy one owing to the perfect conformity of the strata. The difficulties are in addition, enhanced by the facial differences existing in the lithological development of the beds at the various localities.

From a preliminary examination I have decided to draw the boundary at that level above which the bulk of the *Echinidæ* and the characteristic *Pelecypoda*, *Gryphæa vesicularis* and *Ostrea ungulata*, do not ascend, and above which unquestionably new species appear; and this is below the zone of *Radiolites Muschketofli* (No. 3).

II.—Kainozoic group.

1. *Tertiary system.*

A.—Eocene series.

(*a.*) *Lower Eocene.*—(*aa.*) Etage Pathanian.—In the Mazár Drik and Dés section the zone of *Ostrea acutirostris* is overlaid by a series of shales which are capped by a limestone bed of a variable thickness.

At Mazár Drik the shales vary considerably in colour; being at one

[1] I may mention here that although particular attention was given to the matter no traces of the genus *Belemnites* were found in the whole of the upper cretaceous beds either at Mazár Drik or Dés.

place dark blue, almost black, they are almost white westwards, and are black throughout at Dés. In both the localities the shales contain comparatively large quantity of iron pyrites. The iron pyrites occurs irregularly distributed in lumps and nodules throughout the whole thickness and is much disintegrated.

Although I devoted much time to looking for fossils in this bed, I did not succeed in finding a single fossil with the exception of a single ill preserved *Nautilus* sp. which seems to represent *Nautilus sublaevigatus* of the zone of *Ostrea acutirostris.* I thus consider these shales as unfossiliferous.

Towards the upper parts of the shales thin beds of limestone begin to appear the surface of which is locally full of foraminifera. I recognized

Orbitoides socialis,
Operculina rotalifera,
Nummulites granulosa,
Nummulites spec,

but so far I did not succeed in finding any other fossils in the lower part of the limestone. The argillaceous beds begin to disappear, the calcareous beds prevail and the top of the series is formed by a thick bed of limestone containing the fossils as mentioned above. At Mazár Drik this limestone is more or less flaggy, but at Dés it represents the true Pseudo-breccia of Mr. Oldham. Here I found, in addition to the above mentioned species,

Ovula expansa,
Ovula spec.
Nerinea ganesha.

Fossils are extremely rare, and the *Nerinea ganesha* has been recognized by a fragment only, which is however unmistakeable. At Mazár Drik I found nothing but foraminifera, *Alveolina* spec. (melo) ? being here, as at Des, very numerous.

The above fossils are certainly very few in number, but by occurring also in the lower beds they prove that part of the fauna of the cretaceous strata ascend into beds in which true *nummulites* occur.

There is unquestionably a considerable change of facies between the limestone of the zone of *Ostrea acutirostris* and the overlying shales as at Dés for instance; but at southern side of the Mazár Drik anticlinal the lithological difference is less marked, the lower part of the shales containing as they do calcareous beds; in fact those resting immediately on the top of the zone of *Ostrea acutirostris* represent impure limestone beds. But the bedding is quite conformable, and I did not find any evidence tending to prove the existence of an unconformity.

The only striking feature is the absolute want of animal life in the shales. a circumstance which is in strange contrast with the abundance of individuals in the zone of *Ostrea acutirostris* It is difficult to explain this sudden

change ; that some of the species passed this gap is, however, proved by the occurrence of *Ovula expansa*, *Ovula* sp. and *Nerinea ganesha* in the Pseudo-breccia, for which I adopted the name of zone of *Ovula expansa*, but the cause which annihilated the fauna of the zone of *Ostrea acutirostris* it is difficult to explain. Perhaps a sudden subsidence of the coast, as attested by deposit of shales in connection with a volcanic outburst may have been the cause, the acid ash of the eruption destroying all traces of the fauna. The frequent occurrence of the foraminifera and the scarcity of other fossils tend to prove that the strata from the zone of *Ovula expansa* (= Pseudobreccia-alveolina limestone) upwards cannot be of a littoral character.

The stratigraphical position of these beds remains therefore uncertain unless the view here indicated is accepted. If we fix the boundary between cretaceous and tertiary formation, above the *Ostrea limestone* and below the unfossiliferous shales, and consider every thing above the zone of *Ostrea acuti-costris* as belonging to the tertiary age, then we have unquestionably cretaceous species in the lower eocene beds. But if we fix the boundary above the zone of *Ovula expansa* (= Pseudobreccia-alveolina limestone) and consider every-thing below as cretaceous then we have *nummulites* occurring in the higher eocene beds associated with cretaceous species.

In my judgment we cannot tell where the cretaceous formation terminates and the tertiaries begin in Baluchistan. If we are solely guided by lithologi-cal grounds, the zone of *Ostrea acutirostris* would have to be considered as the last cretaceous bed ; but the fauna of this zone is by no means such as could be considered a typical cretaceous fauna ; the number of species it has in common with the true cretaceous beds being very small, while on the other hand a number of new and unquestionably modern types, which I refer to the genus *Conus*, appear. I have already mentioned above the strange similarity which exists between the *Ostrea acutirostris* and an *Ostrea* spec. from the upper beds of the Ranikote (=ghazij, middle eocene) group.

But if we disregard the lithological grounds and are guided by the occurrence of the fossils only, we should have to fix the boundary above the *Zone* of *Ovula expansa*, a view which is untenable.

The only way out of this difficulty would seem to be to accept an inter-mediate position for these beds. In my opinion they are to be correlated with the *Cardita beaumonti* beds of Sind, the fauna of which, though certainly related to that of the cretaceous formation of Baluchistan, exhibits features which cannot be solely explained by a facial difference.

(*bb*) *Etage Ranikotian.*—The lower argillaceous group does not contain a very rich fauna, at least in its lower parts. The fauna is rather monotonous consisting chiefly of various species of *nummulites*. The higher beds have yielded a varied fauna, particularly at Harnai, Sharig and Khost.

So far as I am able to judge from my rather limited experience, the lower parts of the argillaceous group are chiefly characterised by *nummulites* belonging to d'Archiac's section *Striatae*; there are also some other species like *N. perforata* and *N. beaumonti*, *N. ramondi*, but it appears that the Striatæ like *N. granulosa* do not ascend into the higher parts. If this observation were to be found general, an exceedingly good and easily recognisable feature for the further subdivision would be available. Whether the following succession of horizons may hold good for any larger area will have to be proved by further researches.

At the northern side of the Mazár Drik anticlinal I found, immediately above the zone of *Ovula expansa*, *Nummulites perforata* in large numbers; at other places, however, for instance at Dés and Sonari, the same beds were unfossiliferous. Above the *perforata* beds came in *nummulites* spec. nov., a very characteristic species which at Dés and Mazár Drik continued till the next higher horizon; in fact it ascended higher still at Mazár Dirk. South of Duki, a little north of Dabarkote, this species was replaced by *Nummulites ramondi*, but I am unable to say whether this horizon is higher or lower than the spec. nov. horizon; it is probably the former but above the *perforata* horizon.

Above the last named horizon succeeds a series of beds which are characterised by the abundance of a cardita, *Cardita mutabilis* of the Ranikote group. At Mazár Drik and at Dés only a few other species have been found together with this species, but at Harnai numerous other interesting species have been found associated with it, most of them, if not all, being new. Of chief interest is the *Ostrea* aff. *acutirostris* which has here its habitat and does not apparently rise to a higher horizon. Above this bed occur clays with an abundance of *Ostrea lingua* which forms extended banks near Harnai. Above the zone of *Ostrea lingua* comes a thin bed of calcareous limestone full of genus nov. spec. nov. And above that begins probably the Spintangi group as the fauna shows a considerable change. In an earthy soft limestone a smooth *Ostrea* was found which may probably represent a new species. *Melonites melo* begins to appear, and though lithologically still belonging to the argillaceous group, faunistically it should perhaps be included in the next one

At Mazár Drik and at Dés the horizons above the *Cardita mutabilis*-horizon are not developed in the same way as at Harnai; they are here represented by calcareous beds which chiefly contain *nummulites* spec.

The following would indicate my view of the faunistic horizons in descending order:—

	Harnai.	Mazár Drik-Dés.
KHIRTHARIAN.	Nodular limestone .	Soft nodular limestone (?).
	Zone of *Ostrea* spec. nov. .	Flaggy limestone ?.
	Zone of gen. nov. spec. nov.	Nodular limestone full of *Nummulites beaumonti*.
	Zone of *Ostrea lingua* .	
	Zone of *Cardita mutatilis* .	Clay with *Cardita mutabilis*.

RANIKOTIAN	Unfossiliferous clay	Zone of *Nummulites*, spec. nov. Zone of *Nummulites ramondi* (?). Zone of *Nummulites perforata*.
PATHANIAN	*Alveolina* limestone	Zone of *Ovula expansa*.

As already pointed out, this is only an attempt at the classification of an enormous series which had not hitherto been subdivided. I am quite aware that it will be considerably modified in future, but as the fossils have been collected according to the above horizons, with special regard to the lower ones at Mazár Drik-Dés and the upper ones in the Harnai district, the main features of this subdivision may prove correct.

(*b*) *Upper Eocene.* (*aa*) *Etage Khirtharian.*—Though collections have been brought together no attempt has been made for the present to subdivide this group, as at our present state of knowledge of its fauna such attempt would seem somewhat premature.

It was in my opinion as already expressed, doubtful whether the limestone beds at Mazár Drik and Dés which have been considered as Spintangi (upper eocene) were really correlated with the Khirthar group or not. And although I am not yet in a position to give a definite verdict, it seems certain that the limestone series resting upon the Ranikote group is of a much greater thickness near Mazár Drik and Dés than in the Harnai district.

It must be left to future researches to settle the interesting question as to which bed of the Mazár Drik-Dés area the nodular limestone of Harnai, the type of the Spintangi or upper eocene, is to be correlated with. If I may be permitted to express a suggestion, it is that the chert breccia of the Harnai district probably indicates a break, and that the nodular limestone above it is really correlated with the Khirthar group. If this view be correct, it would prove that a considerable part of the series, as developed at Mazár Drik-Dés, representing the upper part of the Ranikote group, is not developed in the Harnai district.

I give this opinion for what it is worth, as it is useless to speculate further than our present knowledge of the actual facts goes, so long as the tertiary fauna has not been thoroughly examined; but the above considerations may perhaps serve as hints in future surveying.

B.—The Miocene Series.—Wherever I observed the Tanishpa beds, as I will call them for the present, the lowest beds exposed always contained several beds almost exclusively composed of two species of *nummulites*, *viz* :

Nummulites sublaevigata.

" *garansensis.*

According to Blanford, these two species always occur just below the

boundary of the miocene, and in Sind at the top of the Nari group. I am not able to test this statement without extended references being looked up, but we may accept it. In this case, the beds characterised by these two species should be considered as representing the Nari group, and the true miocene formation would begin above these beds.

There is no difficulty of a separation at Sur Kach, for instance, where the nummuliferous horizon is developed in the calcareous, coralline facies; but at other localities, as Shingan-Shaigula or at the foot of the hills where the nummuliferous strata occur in an arenaceous series, the beds being in fact nummuliferous sandstones, the fixing of the boundary is extremely difficult as the series imperceptibly pass up into beds containing the miocene fauna.

At Sur Kach the Nari group has a calcareous facies containing a rich fauna of corals. I made a good collection here, which is likely to give interesting results.

Above the nummuliferous beds of the Nari group comes in a series of sandstone and clay beds which are generally unfossiliferous, but here and there thin beds of a costated *Ostrea* spec. which have already been found in the uppermost nummuliferous horizon, appear. This species is associated with a large *Ostrea* having two smooth valves and I consider this as *Ostrea lingua*, but their identity with the similar species occurring in the upper part of the Ranikote (=Ghazij, middle eocene) group near Harnai must be proved by a closer examination.

The costated *Ostrea* disappears and now an interesting fauna chiefly consisting of gastropoda appears. It seems, however, that this fauna is only locally developed as I did not observe it at either Sur Kach, Shingan or Shaigula, but it may be that unaware of its peculiar mode of occurrence I may have overlooked it at these localities. It is certainly not present in the section at Toiwar, and as at Tanishpa it occurs in patches only.

At the above mentioned locality I recognised the following species:—

Arca kurachensis.
Pecten bouei.
Ostrea lingua.
Turritella angulata.
,, *subfasciata.*
Vicarya verneuilli.
Cerithium rude (this is really a new genus).
,, *pseudocorrugatum.*
,, *subtrochleare* (this is a Vicarya).

Above the beds containing this fauna succeeds an enormous thickness of unfossiliferous sandstones and clays which gradually assume a reddish colour. Near Tœsar, at the gorge of the Toi-river, a conglomerate occurring almost at the top of this series was found to contain a large number of bone

fragments, and though I collected a large quantity, there was not a single specimen which was well enough preserved to allow of identification. The bones were rolled, broken, but some of the fragments were of large size.

According to our present state of knowledge, these ossiferous strata should be considered as belonging to the pliocene Siwaliks, and in that case we again experience the same difficulty as before, namely, as to where to draw the boundary between miocene and pliocene? There is no break indicating an unconformity, as there is an uninterrupted series of beds gradually leading up from the marine miocene to beds containing a terrestrial fauna, just as has been observed in Burma.

There can be no doubt that a break exists between the Khirthar (= Spintangi, upper eocene) of Harnai and the Siwaliks, as the whole series from the Nari to the Gaj is either not developed in that part of Baluchistan, or, if originally present, has subsequently been denuded away.

I may be able before long to embody these views in a special paper, but much will have to be done, as for instance a monograph of the Foraminifera, specially of the *Nummulites* of the eocene period, before more than a mere preliminary note can be given.

Baluchistan Desert.

Seistan "Mission."

The Agent to the Governor General and Chief Commissioner of Baluchistan having expressed a desire that the party of the Political Officer at Chagai should be accompanied by a geologist during his usual cold weather tour through the district and up to the Seistan frontier, Mr. Vredenburg was instructed to proceed to Quetta and to join Captain Webb-Ware's party.

The march of the "Mission" did not offer many opportunities of enlarging our knowledge of the geology of that country; Mr. Vredenburg was seldom permitted to do more than keep to the line of march, but nevertheless he managed to connect his observations and in the following short report he gives a summary of what he has seen. He is still in the neighbourhood of Nushki, but will shortly return to head-quarters.

MR. E. VREDENBURG.

Area examined.

While accompanying the Political Assistant's tour in the district of Chagai and adjoining territories, I have had the opportunity of examining geologically part of the desert of north-western Baluchistan and eastern Persia included within the parallels 28° 30′ and 30° N, and the meridians 60° 30 and 66° E.

Physical features.

Two types of physical features are represented in this region: there are ranges of highly folded strata running in parallel ridges, and lower-lying tracts either quite level or occupied by hills of moderately disturbed rocks and somewhat irregular structure. If a map of

Baluchistan be examined, it will be noticed that just north of the latitude of Kelat, the mountainous region consists of a highly folded series of very closely set parallel ranges with a nearly north and south strike, extending from the Indus alluvial plain up to the desert at Nushki, over a breadth of some ninety miles. South of the latitude of Kelat, the ranges diverge in a sheaf-like manner, the outer ones to the east preserve a nearly southerly strike and become the Sind mountains whose geology has been described by Mr. Blanford (Mem. G. S. I., Vol. XVII) ; the more western ranges assume more and more a south-west and finally a westerly direction. In the case of the innermost ridges, the south and westerly trend is so pronounced from the immediate neighbourhood of Nushki, that they soon become separated from the rest of the group by broad intervening deserts and stand out as completely independent ranges. The innermost range forms a low line of heights separated from the next range to the south by the gradually broadening plain that extends from Nushki towards Dalbandin (Lat. 28° 52′, Long. 64° 25′). South of Chagai it rises into the conspicuous Chappar hills west of which its structure becomes confused, and it is gradually lost beneath alluvial deposits. The next range forms an important system of hills several peaks of which rise to heights exceeding 9,000 feet; it runs in a west-south-west direction between the Nushki-Dalbandin depression just mentioned and the broad desert plain of the Kharan Khanat. Its altitude decreases westwards and its last prolongations sink beneath the alluvium of the Mashkhel plain. But to the north-west of the Mashkhel, the folded ranges once more rise above the recent surface deposits, their trend being now north-westerly. At first they cover a very broad area, the ranges are low, the strata presenting gently undulating dips; broad plains like the Tahlab valley and the Dasht-i-Tahlab separate various groups of ridges from one another. But gradually the plains become narrower and the ranges are drawn more closely together, gaining in height, while at the same time the disturbance of the rocks increases. Lastly, towards Koh-i-Malik Siah at the western extremity of the area visited, the disposition of the numerous parallel ranges recalls once more the structure of the Nushki hills.

These mountains encircle the southern margin of an immense low-lying area extending into Afghanistan, where it includes the salt swamps of Gaud-i-Zirreh, the great desert of Registan, and the plain of the Helmand. All these low-lying regions are covered with recent alluvial deposits of varying degrees of coarseness, which usually conceal the underlying rocks. Here and there, however, they are exposed in low hills, usually flat-topped, whose nearly undisturbed strata are in marked contrast with the highly folded and altered rocks of the region of regular parallel ranges. Hills such as those near Tozgi (Lat. 29° 3′, Long. 62° 20′), and those west of Chagai, although they rise well above the plain, belong in reality to those low-lying tracts by their structure and by their mode of disturbance. Here and there they rise

into continuous ridges owing to a locally well marked dip, but nowhere is the strike regular enough to give rise to a definite range. The rocks show sometimes a certain amount of jointing, but never any extreme disturbance, while where the parallel ranges are very close set, as near Nushki and near Koh-i-Malik Siah, slaty cleavage is developed to such an extent as to completely disguise the character of some of the rocks.

Disturbance.

The great northern depression and also the smaller desert plains which further south separate the mountain ranges from one another, must be regarded therefore as areas of minimum disturbance, portions which resisted folding at the time when the mountains were upheaved; they are moreover in many cases real areas of subsidence. This is well shown by the structure of the mountains in their neighbourhood; they exhibit in a marked degree the "scaly structure" which has been so often described in the case of the Alps and Himalayas, and there are numerous examples of thrust planes and overfolds, the thrust being always towards the low lying area, whether that be north or south of the mountains. If all the ranges as far south as the Mekran coast be regarded as one system of mountains, it is probable that, as in the case of the Himalayas, the force which has folded them acted along a north to south direction; but when a depressed area occurs in the midst of the mountainous region, the folded rocks of the northern margin of the range south of it are found to have yielded towards the plain in a northern direction. Thus, in those ranges which I have had the opportunity to study, rising between two depressions, for instance the Saindak ranges bordered by the Mirjawa plain to the south west, and the Gaud-i-Zirreh depression to the north-east, the range assumes a very regular and symmetrical structure; along either margin of the range the strata thrust over the edges of the subsided areas, dip inwards; slaty cleavage becomes gradually more and more pronounced towards the central axis where the cleavage planes become quite vertical.

The contrast which exists between the structure of the parallel ranges and that of the low lying districts does not find its counterpart in any difference of the rocks occurring in them. In either type of country the strata observed are exactly the same; the rocks most commonly met with are sub-marine volcanic tuffs accompanied by limestones and shales, which Mr. Griesbach has identified with the flysch of Europe (Mem. G.S.I., Vol. XVIII, part 1). As in Europe, they belong partly to the upper cretaceous and partly to the lower tertiary; in some places they are conformably overlaid by strata containing a typical eocene fauna, while at other times they are found interbedded with limestones containing hippurites and ammonites. In several sections these rocks pass gradually into an underlying set of shales and sandstones that contain no volcanic material; no distinct fossils have been observed in them, but as the sequence appears per-

Flysch facies.

fectly conformable, it is probable that these strata are not older than cretaceous. The flysch strata are generally so much disturbed that it is not possible to estimate accurately their thickness; judging from the importance of the hills which they constitute, it must be great, probably several thousands of feet. The eocene is represented by a considerable thickness of shales associated with fossiliferous limestone bands, overlaid by a great mass of nummulitic limestone. These rocks appear to bear a great resemblance to the Khirtar and Lower Khirthar of Sind and south-east Baluchistan as described by Mr. Blanford (Mem. G.S.I., XVII, pp. 41-49). It frequently happens that the shales have been affected to such an extent by tangential pressure, that they assume the facies of palæozoic slates, and were it not for an occasional limestone band in which nummulites have been preserved, it would be difficult to realise that the rocks are tertiary.

Siwaliks.

Outcrops of all the rocks above mentioned—the flysch and the sediments underlying and overlying it—occupy areas of variable size throughout the district examined, according to the disposition of synclines and anticlines. The only strata that are restricted to particular regions are the Siwaliks; these occur along the margin of the desert plains in the neighbourhood of the tall ranges of older rocks; as in the case of the Himalayas, they usually dip inwards, that is towards the range which they fringe, the dip being therefore southerly where they occur along the southern edge of a plain. They consist of conglomerates, sandstone and clays, often bright coloured, with veins of calcite and gypsum; they differ but little, except by their high dips, from the recent undisturbed alluvium that overlies them. The recent deposits often attain a considerable thickness, rising into terraces disposed in successive steps of remarkable regularity. Considering that the whole region is an area of closed drainage, it is difficult to regard these terraces as representing the former level of the entire land, gradually removed by denudation as in the case of the river-gravel terraces of regions draining into the sea; those of the Mashkhel drainage area occur in such close proximity to the "Hamun," the lowest level at which any sediment can be deposited that it would be difficult to explain where the denuded materials have been removed to. The nature of the deposits themselves implies the existence of climatic conditions extremely different from those that prevail at the present day, and before dessication had gradually converted the whole region into a desert, the rivers probably supplied sufficient water to form important lakes. The altitude reached then by the water above what is now the dried up bed of the Hamun, would have been the lowest level at which any rivers could have deposited any coarse-grained sediment, and the successive steps of the terraces would correspond to gradually lower surface levels of the dwindling lakes.

The numerous igneous rocks, many of which have already been described by Lieut.-General C. A. McMahon (Quart. Journn. Geol. Soc., Vol. LIII, p.

289) and by Capt. A. H. McMahon, C.S.I., C.I.E. (ibid), and by Mr. Holland (Rec. G.S.I., XXX, p. 125) belong to three distinct periods. The oldest ones are volcanic, forming the basaltic and andesitic tuffs and lavas of the flysch period, already noticed.

Igneous rocks.

The large granite and diorite intrusions forming the peaks of the Kas Koh (Lat. 28°50′, Long. 65°15′), Malik Naro (Lat. 29°20′, Long. 63°29′), Lar Koh (Lat. 29°45′, Long. 60°56′), Koh-i-Khwaja-i Misk (Lat. 29°15′, Long. 60°55′) and many other mountains are probably of upper eocene age; they have been intruded into the newest nummulitic strata, but they are older than the Siwaliks which contain rolled pebbles derived from them. The granites and diorites are so intimately associated that it is not possible to make out which is the older of the two; they appear to have been intruded simultaneously. The latest rocks of plutonic series are narrow branching and anastomosing basic dykes running through the granite and into the surrounding sedimentary rocks.

The newest igneous rocks are again a volcanic series; they are mostly andesites, and, both as lavas and subaërial tuffs, constitute a number of recent and sub-recent volcanoes, the largest of which is the Koh-i-Taftan. Owing to the limited time at my disposal, I only examined the northern portion of this mountain; if the volcanic deposits extend to as great a distance south of the summit as they do on the northern side, they must cover a superficies with a diameter of no less than twenty-five miles. The older eruptions were mainly explosive, the latter ones entirely effusive; the centre of eruption has never shifted to any considerable extent, thus giving rise to a very regular cone of striking beauty. Great masses of vapour visible from a distance of many miles constantly rise from the summit of the cone; there are numerous fumaroles along its southern slopes.[1] The Koh-i-Sultan is another andesitic volcano, but it has long been extinct; instead of a single centre of eruption, there are three foci placed along a straight line, from which three overlapping cones were formed, now greatly ruined by denudation. The phases of activity have been much the same as in the case of the Koh-i-Taftan. The earlier eruptions were mostly explosive, forming considerable beds of ashes and agglomerates, and were followed by the outpouring of great sheets of lava. The ash-beds and agglomerates have become so much indurated that they resist disintegration almost as well as the compact lavas, which accounts for the manner in which erosion has carved them into the precipitous cliffs and peaks that have been described by Captain McMahon (Geographical Journal, Vol. IX, p. 392, and Quart. Journ. Geol. Soc., Vol. LIII, p. 289). As in the case of Koh-i-Taftan, the last stage of the volcano was that of a solfatara. An area of more than two square miles round the peak

[1] This information was communicated to me by Mr. Wood, of the Persian Telegraph, who visited the southern side of the mountain a few months ago.

called "Miri," and several smaller patches further west, show the tuffs and lavas entirely transformed by the action of mineralising vapours into soft clays, either white, or brilliantly coloured red and yellow. They are impregnated with sulphate of alumina and contain crystallisations of gypsum and sulphur. The volcano Damodim, a few miles further west, reproduces the main features of Koh-i-Sultan on a smaller scale.

These two volcanoes have long been extinct, but a number of quite recent cones are scattered throughout their neighbourhood. They consist entirely of andesitic lava which has been erupted in a very viscous state, consolidating in steep-sided, bell-shaped masses, very similar in their outline and probably in their mode of formation to the trachytic bosses of the Puy de Dôme type. The largest is the Koh-i-Dalil (Lat. 29° 8', Long. 62° 14'). Another, of very recent date, is Batil Koh on the southern slopes of Koh-i-Sultan: it stands on the talus of loose materials formed by the denudation of Koh-i-Sultan in such a manner as to show that there has been practically no further erosion since the time of its eruption.

Very recent also are the deposits of travertine, specimens of which had been collected by some of the earliest explorers (Rec. XXX. G.S.I., p. 129); the carbonate of lime was deposited by springs, now exhausted, and forms terraces similar to those that have been described in other volcanic districts.

CALCUTTA;
31st March 1899.

C. L. GRIESBACH.
Director, Geological Survey of India.

Appendix I.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India, from the 1st April 1898 to the 31st March 1899.

ADELAIDE.—Royal Society of Australia.
BALTIMORE —Johns Hopkins University.
BASEL.—Naturforschende Gesellschaft.
 „ Schweizerischen Paläontologischen Gesellschaft.
BATAVIA.—Kon. Natuurkundige Vereeniging in Ned.-Indie.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
 „ K. Preuss. Akad. der Wissenschaften.
 „ K. Preuss. Geologische Landesanstalt.
BERN.—Geologischen kommission der Schweig Naturforschenden Gesellschaft.
BOLOGNA.—R. Accad. delle Scienze dell' Istituto de Bologna.
BOMBAY.—Bombay Branch of the Royal Asiatic Society.
 „ Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
 „ Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterlandische Cultur.
BRISBANE.—Queensland Branch of the Royal Geog. Soc. of Australasia.
 „ Royal Society of Queensland.
BRISTOL.—Museum and Library.
 „ Naturalists' Society.
BRUSSELS.—Société Royale Belge de Geographie.
 „ Académie Royale des Sciences des Lettres et des Beauxarts de Belzique.
BUCHAREST.—Museului de Geologia si di Paleontologia.
BUDAPEST.—Kön. Ungarische Geologische Anstalt.
 „ Ungarische Geologische Gesellschaft.
 „ „ National Museum.
BUENOS AIRES.—Acad. Nacional de Ciencias.
BUFFALO.—Society of Natural History.
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
 „ Asiatic Society of Bengal
 „ University of Calcutta.
 „ Editor, Indian and Eastern Engineer.
CAMBRIDGE.—Philosophical Society.
 „ Woodwardian Museum.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CANADA.—Hamilton Association.

CASSEL.—Vereins für Naturkunde.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Academié Royale des Sciences et des Lettres.
DES MOINES.—Iowa Geological Survey.
DRESDEN.—K. Min Geol. und Præhistorische Museum.
„ Naturwissenschaptliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
„ „ „ Society of Arts.
FREIBURG.—Naturforschende Gesellschaft.
GLASGOW.—Glasgow University.
„ Philosophical Society.
GOTHA.—Editor, Petermann's Geog. Mittheilungen.
GÖTTINGEN.—Königl. Gesells. der Wissenschaften.
HALIFAX.—Nova Scotian Institute of Science.
HALL.—Academia Cæsarea Leop. Carol. Nat. Curiosorum.
INDIANAPOLIS.—Indiana Academy of Science.
KÖNIGSBERG.—König. Physikalische Ökonomische Gesellschaft.
LA PLATA.—Museo de La Plata.
LAUSANNE—Société Vaudoise des Sciences Naturelles.
LAWRENCE.—Kansas University.
LEEDS.—Yorkshire College.
LEIPZIG.—Kön. Säch. Gesells. der Wissenschaften.
„ Vereins für Erdkunde.
LIÈGE.—Société Geol. de Belgique.
LILLE.—Geologique du Nord.
LISBON.—Section des Travaux Geol. du Portugal.
LIVERPOOL.—Geological Society.
„ Literary and Philosophical Society.
LONDON.—British Museum (Natural History).
„ Geological Society.
„ British Association for the Advancement of Science.
„ Geological Survey of the United Kingdom.
„ Iron and Steel Institute.
„ Linnean Society.
„ Royal Geographical Society.
„ „ Institution of Great Britain.
„ „ Society.
„ Society of Arts.
„ Zoological Society.
„ Imperial Institute.
MACON.—L' Institut Golonial de Marseille.
MARSEILLE.—Faculte des Sciences.
MADRID.—Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.

MELBOURNE.—Australasian Institute of Mining Engineers.
„ Dept. of Mines and Water-Supply, Victoria.
„ Geological Survey of Victoria.
„ Royal Society of Victoria.
MEXICO.—Instituto Geologico de Mexico.
MILAN.—Sociéta Italiana di Scienze Naturali.
MOSCOU.—Société Imp. des Naturalistes.
MUNICH.—König. Bayerische Akad. der Wissenschaften.
„ Königlichen Sternwarte (zu Bogenhausen).
NAPLES.—Seale Accademia delle Scienze Fisiche e Matematiche.
NEW CASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
„ American Museum of Natural History.
OTTAWA.—Geological and Natural History, Survey of Canada.
PARÁ.—Museu Paraense de Historia Naturalle Ethnographia.
PARIS.—Department of Mines.
„ Editor, Annuaire Geologique Universel.
„ Ministere des Travaux Publics.
„ Museum d' Histoire Naturelle.
„ Société de Geographie.
„ „ Geologique de France.
PENZANCE.—Royal Geographical Society of Cornwall.
PERTH.—Geological Survey, Western Australia.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Societa Toscana de Scienze Naturali.
PRETORIA.—State Mining Department.
RIO-DE-JANEIRO.—Imperial Observatory.
ROME.—Reale Accad. dei Lincei.
„ „ Comitato Geologico d' Italia.
„ „ Societa Geologica Italiana.
SALEM.—American Association for the Advancement of Science.
„ Essex Institute.
SAN FRANCISCO.—California Acad. of Sciences.
SINGAPORE.—Straits Branch of the Royal Asiatic Society.
SHANGHAI.—China ditto ditto.
STOCKHOLM.—Kõng. Svenska Vetenskaps Akademie.
ST. PETERSBURG.—Académie Imperiale des Sciences.
„ Comité Geologique.
„ Musée Geologique de l' Universite Imperiale.
„ Russ. Kaiser. Mineralogische Gesells.
SYDNEY.—Australian Museum.
„ Geological Survey of New South Wales.

SYDNEY.—Linnean Society of New South Wales.
„ Royal Society of ditto.
TAIPING.—Perak Museum.
TOKIO.—College of Science, Imperial University.
„ Deutsche Gesellschaft für Natur-und Volkerkunde-Ostasiens.
TORONTO – Canadian Institute.
TURIN.—Osservatorio della R. Universita.
„ Reale Accad. delle Scienze.
UPSALA.—Upsala University.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA —K. Akad. der Wissenschaften.
„ K. K. Geog. Gesellschaft.
„ K. K. Geol Reichsanstalt.
„ K. K. Naturhistorischen Hopmuseum.
WASHINGTON.—Smithsonian Institution.
„ U. S. Coast and Geodetic Survey.
„ „ Dept. of Agriculture.
„ „ Geological Survey.
„ „ National Museum.
„ „ National Academy of Science.
WELLINGTON.—Mines Dept., New Zealand.
„ New Zealand Institute.
ZÜRICH —Naturforschende Gesellschaft.
The Governments of Bengal, Bombay, Burma, India, Madras, and the Punjab.
The Chief Commissioner of Assam.
The Resident, Hyderabad.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL 1898 TO 31ST MARCH 1899.

Books and Pamphlets, etc.

ALCOCK, *A.*—An account of the Deep-Sea Madreporaria collected by the Royal Indian Marine Survey Ship *Investigator*. 4° Calcutta, 1898.

BECK, *L.*—Die Geschichte des Eisens. Band IV, lief 2-4. 8° Braunschweig, 1898.

BERWERTH, *F.*—Mikroskopische Structurbilder der Massengesteine. Lief 3. 4° Stuttgart, 1898.

BOGDANOWITSCH.—Geological Researches in Eastern Turkistan. Part II. 4° St. Petersburg, 1892.

BORCHERS, *W.*, and MCMILLAN, *W. G.*—Electric Smelting and Refining. 8° London, 1897.

BOULENGER, *G. A.*—The tailless Batrachians of Europe. Part I. 8° London, 1898.

BRONN, *H. G.*—Klassen und Ordnungen des Their-Reichs—Supplement Band III, livr. 11-20. Band IV, livr. 56-58, and Supplement Band IV,

livr. 5-13. Band V, Abth II, livr. 47-52. Band VI, Abth V, livr. 51-53. 8° Leipzig, 1898.

BROTHERS, *A.*—A Manual of Photography. 8° London, 1899.

CHAUVENET, *W.*—Spherical and Practical Astronomy. Vols. I-II. 8° Philadelphia, 1896

CLANCEY, *J. C.*—Aid to Land Surveying. Larger Edition (2 copies). Flsc. Calcutta, 1882.

COLE, *G.*—Aids in Practical Geology. 3rd Edition (2 copies). 8° London, 1898.

COMELATI, *G.*, and DAVENPORT, *J.*—A New Dictionary of the Italian and English Languages. Vol. I, Italian-English, and II, English-Italian. 8° London, 1854.

COSSMANN, *M.*—Mollusques Éoceniques de la Loire-Inférieure. Fax. 3. 8° Nantes, 1897.

COX, *H. S.*—Prospecting for Minerals—A practical hand-book for prospectors, explorers, settlers, and all interested in the opening-up and development of new lands. 8° London, 1898

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DE RIAZ, *A.*—Description des Ammonites des couches a Peltoceras transversarium. Fol. Lyon, 1898.

DES CLOIZEAUX, *A.*—Manuel Mineralogie. Tome II, fasc. 2. 8° Paris, 1874-1893.

FALB, *R.*—Gedanken und Studien über den Vulcanismus. 8° Graz, 1875.

FICHEUR, *E.*—Matériaux pour la Carte Géologique de L'Algerie, 2nd series, Stratigraphie Descriptions, Regionales. No. 1. La Kabylie du Djurjura. 4° Alger, 1891.

FOQUÉ, *F.*—Les Tremblements de Terre. 8° Paris, 1889.

GÆDICKE, *J.*—Der Gummidruck, No. 10. 8° Berlin, 1898.

GEIKIE, *A.*—Founders of Geology. 8° London, 1897.

General Report and Statistics of Mines and Quarries for 1897. Part I, District Statistics. Part II, Labour. Part III, Output. Flsc., London, 1898.

GODWIN-AUSTEN, *H. H.*—Land and Freshwater Mollusca of India, including South Arabia, Baluchistan, Afghanistan, Kashmir, Nepal, Burma, Pegu, Tenasserim, Malay Peninsula, Ceylon, and other islands of the Indian Ocean. Vol. II, Parts 7-8, with plates. 8° and 4° London, 1897-98.

GOLDMANN, *C. S.*—South African Mines, their position, results and developments, together with an account of diamond, land, finance and kindred concerns. Vols. I-III, with maps and plans. 4° London, 1895-96.

GRAHN, *E.*—Die Städtische Wasserversorgung im Deutschen Reiche, soure in einigen nachbarländern. Band I. 4° Munchen und Leipzig, 1898.

GÜNTHER, *S.*—Handbuch der Geophysik. Band II, lief 7-10. 8° Stuttgart, 1893-99.

HEDIN, *Sven.*—Through Asia. Vols. I-II. 8° London, 1898.

HINTZ, *C.*—Handbuch der Mineralogie. Band I, lief 1. 8° Leipzig, 1898.

JAYNE, *H.*—Mammalian Anatomy. A preparation for Human and comparative anatomy. 8° London and Philadelphia, 1898.

JERVIS, *G.*—I Tesori Sotterranei dell'Italia. Parts 3-4. 8° Torino, 1881-1889.

LACROIX, *A*—Mineralogie de la France et de Ses colonis. Vol. I, parts 1-2, and II, part I. 8° 1893—96

LEWIS, *H. C.*—Papers and notes on the genesis and Matrix of the diamond. 8° London, 1897.

MILNE, *J.*—Earthquake and other earth movements. 4th Edition. 8° London, 1898.

„ Seismology 8° London, 1898.

MURRAY, *J. A. H.*—A new English Dictionary on Historical Principles. Vol. IV (Frank-law-Fyz—Germanizing) and V. (H—Heel.). 4° Oxford, 1898.

NAUMANN, CARL FRIEDRICH.—Elemente der Mineralogie, 13th Edition. 8° Leipzig, 1897-98.

POMEL, *A.*—Paléontologie Monographies :—

Bubalus Antiquus.
Caméliens et Cervides.
Bœufs—Taureaux
Les Bosélaphes Ray.
„ Antilopes Pallas.
„ Rhinoceros Quaternaires.
„ Elephants „
„ Hippopotames.

4° Alger, 1893—96.

POTONIE, *H*—Lahrbuch der pflanzenpalæontologie. Lief 3. 8° Berlin, 1898.

Review of the Mineral Productions in India for 1897. Flsc. Calcutta, 1898.

ROSENBUSCH, *H.*—Mikroskopische Physiographie der Petrographisch wichtigen Mineralien. 3rd Edition, Vols I-II (2 copies). 8° Stuttgart, 1892—96.

„ Elemente der Gesteinslehre. 8° Stuttgart, 1898.

ROTHPLETZ, *A*—Ein geologischer Querschnitt durch die Ost-Alpen. 8° Stuttgart, 1894.

RUSSELL, *I. C.*—Volcanoes of North America. 8° New York, 1897.

SACCO, *F.*—I Molluschi de Terreni Terziariidel Piemonte e della Liguria. Part XXV. 4° Torine, 1898.

SARS, *G. O.*—Mollusca Regionis Arcticæ Norvegiœ. 8° Christiania, 1878.

SCHMIDT, *H.*—Das Fernobjektiv No. 9. 8° Berlin, 1898.

SEWARD, *A. C.*—Fossil plants for students of botany and geology. Vol. I. 8° Cambridge, 1898.

SCOTT, *W. B.*—An Introduction to Geology. 8° New York, 1897.

STÖBEL, *A.*—Die Vulkanberge von Ecuador Geologisch-Topographisch aufgenommen und Beschrieben. 4° Berlin, 1897.

SUPAN, *A.*—Grundzüge der Physischen Erdkunde, Auplage 2. 8° Leipzig, 1896.

SZECHENYI, GRAF. BELA.—Die Wissenschafthche ergebnisse der reise des

Grafen Bela Széchenyi in Ostasien, 1877—80. Band II. 4° Wien, 1898.

THRELFALL, *R.*—On Laboratory Arts. 8° London, 1898.

TROUESSART, *E. L.*—Catalogus Mammalium. Fasc. I—V. 8° Berolini, 1897-1898.

TRYON, *G. W.*—Manual of Conchology, 1st series, parts 66-67, and 2nd series parts 42-43. 8° Philadelphia, 1897-98.

Verhandlungen der Kommission behufs Erörterung von Makregeln zur Hebung und Befestigung des Silbermerths. Band I-II, 8° Berlin, 1894.

PERIODICALS, SERIALS, ETC.

American Geologist. Vol. XXI, No. 3, to Vol. XXIII, No. 2. 8° Minneapolis, 1898-99.

„ Journal of Science, 4th Series, Vol. V, Nos. 27-30, and VI, No. 32, to VII, No. 38. 8° New Haven, 1898-99. THE EDITOR.

„ Naturalist, Vol. XXXII, No. 374, to XXXIII, No. 386. 8° Philadelphia, 1898-99.

Annalen der Physik und Chemie. Band LXIV, heft 3, to LXVII, heft 2. 8° Leipzig, 1898-99.

Annales de Geographie, Annee VI, No. 30, to VII, No. 35. 8° Paris, 1898.

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Annals and Magazine of Natural History, Vol. I, No. 4, to Vol. III, No. 15. 8° London, 1898-99.

Annuaire Geologique Universel. Tome XIV. 8° Paris, 1898. THE EDITOR.

Athenœum. No 3673—3724. 4° London, 1898-99.

Beiblätter zu den Annalen der Physik und Chemie. Band XXII, No. 3, to XXIII, No. 2. 8° Leipzig, 1898-99.

Beiträge zur Geophysik. By G. Gerland. Band III, heft 4. 8° Leipzig, 1898.

Chemical News. Vol. LXXVII, No. 1999, to Vol. LXXIX, No. 2050. 8° London, 1898-99.

Colliery Guardian. Vol. LXXV, No. 1942, to Vol. LXXVII, No. 1993 Fol. London, 1898-99.

Geographische Abhandlungen. Band VI, heft 3. 8° Wien, 1898.

Geological Magazine. New series, Decade IV, Vol. V, No. 4, to Vol. VI, No. 3. 8° London, 1898-99.

Indian and Eastern Engineer, New series, Vol. II, Nos. 4—12, and IV, Nos. 1-3. 4° Calcutta, 1898-99.

Industries and Iron, Vol XXIV, No. 1314, to Vol. XXVI, No. 1365. 4° London, 1898-99.

Jahrbuch der Astronomie und Geophysik. Herausgegeben von Dr. Hermann J. Klein. Jahrgang VIII. 8° Leipzig, 1898.

Journal de Conchyliologie, Vol. XLV, Nos. 2—4, and XLVI, No. 1. 8° Paris, 1897-1898.

Journal of Geology, Vol. VI, Nos. 1—8, and VII, No. 1. 8° Chicago, 1898-99.

London, Edinburgh, and Dublin Philosophical Magazine. Vol. XLV, No. 275 to Vol. XLVI, No. 286. 8° London, 1898-99.

Mineralogical Magazine. Vol. XII, No. 54. 8° London, 1898.

Mining Journal. Vol. LXVIII, No. 3264, to LXIX, No. 3315. Fol. London, 1898-99

Natural Science. Vol. XII, No. 74, to Vol. XIII, No. 85. 8° London, 1898-99.

Nature. Vol. LVII, No. 1481, to Vol. LIX, No. 1532. 8° London, 1898-99.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Jahrg. 1896. Band II, heft 3; 1898, Band I, heft 2-3; II, heft 1-3, and 1899, Band I, heft 1-2. 8° Stuttgart, 1896 and 1898-99.

„ Beilage—Band XI, heft 3, and XII, heft 1-2. 8° Stuttgart, 1898-99.

Palæontographica. Band XXX, lief 2, XLIV, lief 5-6 and XLV, lief 1—5. 4° Stuttgart, 1897-98.

Palæontologische Abhandlungen Neue Folze, Band IV, heft 2. 4° Jena, 1898.

Petermann's Geographischer Mittheilungen. Band XLIV, No. 3, to XLV, No. 2. 4° Gotha, 1898-99.

Revue Critique de Paléozoologie. Vol. I, parts 1—4, and II, parts 2-3, by M. Cossmann. 8° Paris, 1897-98.

Scientific American. Vol. LXXVIII, No. 10, to Vol. LXXIX, No. 8. Fol. New York, 1898-99.

„ „ Supplement, Vol. XLV, No. 1157, to Vol. XLVII, No. 1208. Fol. New York, 1898-99.

Tschermak's Mineralogische und Petrographische Mittheilungen. Vol. XVII, heft 6, and XVIII, heft 1—4. 8° Vienna, 1898-99.

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„ Praktische Geologie. heft 4, 1898, and heft 1-2, 1899. 8° Berlin, 1898-99.

Zoological Record. Vol. XXXIV. 8° London, 1898.

GOVERNMENT SELECTIONS, REPORTS, ETC.

ASSAM.—Report on the Administration of the Province of Assam for 1897-98. Flsc. Shillong, 1899. CHIEF COMMISSIONER, ASSAM.

„ Report on the effect produced by the Earthquake on the Levels, Drainage, and Navigation of certain parts of Assam, by Pandit Matadin Sukul. Flsc. Assam, 1898

CHIEF COMMISSIONER, ASSAM.

Bengal.—Reports on the Administration of Bengal for 1897-98. Flsc Calcutta, 1899. BENGAL GOVERNMENT.

BOMBAY.—Brief sketch of the Meteorology of the Bombay Presidency for 1897-98. Flsc. Bombay, 1898. BOMBAY GOVERNMENT.

„ Magnetical and Meteorological Observations made at the Government Observatory, Bombay, for 1896. Flsc. Bombay, 1897.

BOMBAY GOVERNMENT.

„ Reports on the Administration of the Bombay Presidency for 1897-98. Flsc. Bombay, 1898. BOMBAY GOVERNMENT.

„ Selections from the Records of the Bombay Government. New series, Nos. 361, 364—366, 370 and 372. Flsc. Bombay, 1898.

BOMBAY GOVERNMENT.

BURMA.—Report on the Administration of Burma for 1897-98. Flsc. Rangoon, 1898. BURMA GOVERNMENT.

" Thirty-First Annual Report of the Light-houses and Light-vessels off the coast of Burma. Flsc., Rangoon, 1898. BURMA GOVERNMENT.

HYDERABAD.—Report on the Administration of the Hyderabad Assigned Districts for 1897-98. Flsc., Hyderabad, 1898. RESIDENT, HYDERABAD.

INDIA.—Administration Report on the Railways in India. Parts I-II for 1897-98. Flsc., Calcutta, 1898. GOVERNMENT OF INDIA.

" Agricultural Ledger. Nos. 18 and 20 (1897), and Nos. 1—20 (1898). 8° Calcutta, 1897-98. GOVERNMENT OF INDIA.

" Annual Statement of the Trade and Navigation of British India with foreign countries and of the coasting trade in the year ending 31st March 1898. No. XXXII, Vols. 1-2. 4° Calcutta, 1898. GOVERNMENT OF INDIA.

" Civil Budget Estimates of the Government of India for 1898-1899. Flsc. Calcutta, 1898. GOVERNMENT OF INDIA.

" History of Services of Officers holding gazetted appointments in the Home, Foreign, Revenue and Agricultural, and Legislative Departments, corrected to 1st July 1898. 8° Calcutta, 1898. GOVERNMENT OF INDIA.

" List of Civil Officers holding gazetted appointments under the Government of India in the Home, Legislative, Foreign and Revenue and Agricultural Departments, corrected to 1st January and 1st July 1898, and 1st January 1899. 8°, 1898-99. GOVERNMENT OF INDIA.

" List of Officers in the Survey and other Scientific Minor Departments subordinate to the Government of India in the Department of Revenue and Agriculture, corrected to 1st July 1898, and 1st January 1899. 8° Calcutta, 1898-99. GOVERNMENT OF INDIA.

" List of Officers of the Geological Survey of India, corrected to 1st July 1898 and 1st January 1899. 8°, 1898-99. GOVERNMENT OF INDIA.

" Meteorological Department—

Administration Report, 1897-98. 4° Calcutta, 1898.

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INDIA.—Report on the Administration of Andaman and Nicobar Islands for 1896-97 and 1897-98. Flsc., Calcutta, 1898.
GOVERNMENT OF INDIA.

„ Report on the Natural History Results of the Pamir Boundary Commissions. Flsc., Calcutta, 1898. GOVERNMENT OF INDIA.

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„ Selections from the Records of the Government of India, Foreign Department, Nos. 351, 357, 359-360, 363. Flsc., Calcutta, 1897—1899. GOVERNMENT OF INDIA.

MADRAS.—Administration Report of the Madras Government Museum for 1897-98. Flsc., Madras, 1898. MADRAS GOVERNMENT.

„ Annual Administration Report of the Forest Department, Madras Presidency, for 1896-97. Flsc., Madras, 1898.
MADRAS GOVERNMENT.

„ Manual of the Coimbatore District, Vol. II. 8° Madras, 1898.
MADRAS GOVERNMENT.

„ Report on the Administration of the Madras Presidency for 1897-98. Flsc., Madras, 1898. MADRAS GOVERNMENT.

NORTH-WESTERN PROVINCES AND OUDH.—Minutes of the Managing Committee, Provincial Museum, North-Western Provinces and Oudh, April 1894 to March 1896. Flsc., Allahabad, 1898.
GOVERNMENT OF THE N.-W. P. AND OUDH.

PUNJAB.—Annual report of the Department of Land Records and Agriculture, Punjab, for the year ending 30th September 1897. Flsc., Lahore, 1898. PUNJAB GOVERNMENT.

„ Report on the Land Revenue Administration of the Punjab for the Agricultural year, 1st October 1896 to 30th September 1897, Flsc., Lahore, 1898. PUNJAB GOVERNMENT.

„ Final report of the Peshawar District for 1898. Flsc., Lahore, 1898.
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Thirty-first Annual Report of the Colonial Laboratory. 8°, 1898.
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MAPS.

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BUDAPEST.—Hungarian Geological Institute—
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HELSINGFOSS.—Finlands Geologiska Undersökning suomen Geologinen Tuktimus. Sheet Nos. 32—33. 1 : 200,000. Fol. 1894.
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PERTH.—Geological Survey, Western Australia—
Geological Maps of Northampton, and Coollie Coal-field, by A. Gibb Maitland. Fol., 1898.
ROME.—Carta Geol. d' Italia, Fo. 1—4 and Tav. 1—3. 1: 50,000. Fol., 1897.
WASHINGTON.—United States Geological Survey—
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Appendix II.

The Inspector of Mines in India.

Mr. James Grundy.

I have to report that the number of mines inspected during the calendar year 1898 was forty-four. The Inspector of Mines has submitted his report to me in MS., from which it appears that no practical results can be hoped for until legislation has been passed which will compel mining companies to furnish reports to Government at stated periods.

CALCUTTA: }
The 31st March 1899. }

C. L. GRIESBACH, *Director*.

Geological Survey of India.

G. I. C. P. O.—No. 3 D. G. Survey.—11-6-99.—500.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1899

TO THE 31ST MARCH

1900.

GEOLOGICAL SURVEY OF INDIA.

Director.

C. L. Griesbach, C.I.E., F.G.S.

Superintendents.

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A. E. MacA. Audsley.

Museum Assistant.

T. R. Blyth.

Geological Museum, Library, and Office, Calcutta.

MEMOIRS OF THE GEOLOGICAL SURVEY OF INDIA

VOL. I. Royal 8vo, pp. 309, 1859 (*out of print*). Pt. 1, 1856 (*price* 1 Re.): Preliminary notice on the Coal and Iron of Talchir.—On the geological structure and relations of the Talchir Coal-field.—Gold-yielding deposits of Upper Assam.—On specimens of gold and gold dust from Shué-gween. Pt. 2, 1858 (*price* 2 Rs.): On the geological structure of a portion of the Khasi Hills.—On the geological structure of the Nilghiri Hills (Madras). Pt. 3, 1859 (*price* 2 Rs.): On the geological structure and physical features of the Districts of Bankura, Midnapore, and Orissa.—On the laterite of Orissa. On some fossil fish-teeth of the genus Ceratodus, from Maledi, south of Nagpur.

VOL. II. Royal 8vo, pp. 341, 1859 (*out of print*). Pt. 1, 1860 (*price* 2 Rs.): On the Vindhyan Rocks, and their associates in Bundelkand. Pt. 2, 1860 (*price* 3 Rs.) On the geological structure of the central portion of the Nerbudda District.—On the tertiary and alluvial deposits of the central portion of the Nerbudda Valley.—On the geological relations and probable geological age of the several systems of rocks in Central India and Bengal.

VOL. III. Royal 8vo, pp. 438. Pt. 1, 1863 (*price* 3 Rs.) (*out of print*). On the geological structure and relations of the Raniganj Coal-field.—Additional remarks on the geological relations and probable geological age of the several systems of rocks in Central India and Bengal.—Indian Mineral Statistics, I. Coal. Pt. 2, 1864 (*price* 2 Rs.): On the Sub-Himalayan Ranges between the Ganges and Ravi.

VOL. IV. Royal 8vo, pp. 450. Pt. 1, 1863 (*price* 2 Rs.): Report on the Cretaceous Rocks of Trichinopoly District, Madras. Pt. 2, 1864 (*price* 2 Rs.) (*out of print*):* On the structure of the Districts of Trichinopoly, Salem, &c. Pt. 3, 1865 (*price* 1 Re.): On the Coal of Assam, &c.

VOL. V. Royal 8vo, pp. 354. Pt. 1, 1865 (*price* 3 Rs.) (*out of print*): Sections across N.-W. Himalaya, from Sutlej to Indus.—On the Gypsum of Spiti. Pt. 2, 1866 (*price* 1 Re.): On the Geology of Bombay. Pt. 3, 1866 (*price* 1 Re.) (*out of print*): On the Jheria Coal-field.—Geological Observations on Western Tibet.

VOL. VI. Royal 8vo, pp. 395. Pt. 1, 1867 (*price* 8 As.): On the Neighbourhood of Lynyan, &c., in Sind.—Geology of a Portion of Cutch. Pt. 2, 1867 (*price* 2 Rs.) (*out of print*): Bokáro Coal-field.—Rámgarh Coal-field.—Traps of Western and Central India. Pt. 3, 1869 (*price* 2 Rs. 8 As.): Tapti and Nerbudda Valleys.—Frog-beds in Bombay—*Oxyglossus pusillus*.

VOL. VII. Royal 8vo, pp. 342. Pt. 1, 1869 (*price* 3 Rs.): Vindhyan Series.—Mineral Statistics.—Coal.—Shillong Plateau. Pt. 2, 1870 (*price* 1 Re.): Karharbári Coal-field.—Deoghar Coal-field. Pt. 3, 1871 (*price* 1 Re.): Aden water-supply.—Káranpura Coal-fields.

VOL. VIII. Royal 8vo, pp. 353. Pt. 1, 1872 (*price* 4 Rs.): On the Kadapah and Karnul Formations in the Madras Presidency. Pt. 2, 1872 (*price* 1 Re.): Itkhuri Coal-field.—Daltonganj Coal-field.—Chope Coal-field.

VOL. IX. Royal 8vo, pp. iv, 358. Pt. 1, 1872 (*price* 4 Rs.): Geology of Kutch. Pt. 2, 1872 (*price* 1 Re.): Geology of Nagpúr.—Geology of Sirban Hill.—Carboniferous Ammonites, pp. 65.

VOL. X. Royal 8vo, pp. 359. Pt. 1 (*price* 3 Rs.): Geology of Madras.—Sátpura Coal-basin. Pt. 2, 1874 (*price* 2 Rs.): Geology of Pegu.

VOL. XI. Royal 8vo, pp. 338. Pt. 1, 1874 (*price* 2 Rs.): Geology of Dárjiling and Western Duars. Pt. 2, 1876 (*price* 3 Rs.): Salt-region of Kohát, Trans-Indus.

VOL. XII. Royal 8vo, pp. 363. Pt. 1, 1877 (*price* 3 Rs.): South Mahrátta Country. Pt. 2, 1876 (*price* 2 Rs.): Coal-fields of the Nága Hills.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1899

TO THE 31ST MARCH

1900.

UNDER THE DIRECTION OF

C. L. GRIESBACH, C.I.E., F.G.S.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA.
1900.

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

CONTENTS.

GEOLOGICAL SURVEY OF INDIA.

DIRECTOR.

C. L. GRIESBACH, C.I.E., F.G.S., on tour to Madras, 7th June to 4th July 1899; on tour to Central Provinces, Rajputana, and Gujarat, 5th February to 19th March 1900.

SUPERINTENDENTS.

1. R. D. OLDHAM, A.R.S-M., F.G.S., on furlough from 11th July 1899.
2. TOM D. LATOUCHE, B.A., privilege leave for 3 months, availed of from 19th April 1900.
3. C. S. MIDDLEMISS, B.A., also Curator from 1st to 30th April 1899, *vice* Dr. T. L. Walker.

DEPUTY SUPERINTENDENTS.

1. P. N. BOSE, B. Sc. (London), F.G.S., on privilege leave from the 15th May to the 29th June 1899.
2. T. H. HOLLAND, A.R.C.S., F.G.S., also Curator from 1st May 1899, *vice* Mr. Middlemiss, and Officiating Superintendent from 6th July 1899, *vice* Mr. R. D. Oldham.
3. P. N. DATTA, B. Sc. (London), F.G.S.
4. F. H. SMITH, A.R.C.S.

ASSISTANT SUPERINTENDENTS.

1. H. H. HAYDEN, B.A , B.E., also Officiating Deputy Superintendent from 6th July 1899, *vice* Mr. T. H. Holland.
2. E. VREDENBURG, B.L., B. Sc. (Paris), A.R.C.S.
3. T. L. WALKER, M.A. (Kingston), Ph. D. (Leipzig), confirmed in the grade from 8th May 1899.
4. A. KRAFFT von Dellmensingen, Ph. D. (Vienna). Passed the examination in Hindustani by the Lower Standard on 1st May 1899.

PALÆONTOLOGIST.

FRITZ NOETLING, Ph.D. (Berlin), F.G.S.

SPECIALISTS.

1. G. A. STONIER, A.R.S.M., F.G.S., appointed by the Secretary of State for India as Specialist in Mining and Metallurgy for 5 years, and joined this Department on 4th October 1899.
2. G. F. READER, F.G.S., appointed by the Secretary of State for India as Coal Mining Specialist for 5 years. Arrived in Calcutta on 31st October 1899, and joined this Department on 1st November 1899.
3. F. H. HATCH, PH. D., A.M.I.C.E., appointed by the Secretary of State for India as Gold Mining Expert for one year. Arrived in Bombay 31st March 1900 and assumed his duties from that date.

SUB-ASSISTANTS.

1. HIRA LAL, on furlough from 1st April to 4th September 1899.
2. KISHEN SING, on privilège leave from 23rd August to 7th October 1899.

ARTIST.

H. B W. GARRICK.

REGISTRAR.

A. E. MACA. AUDSLEY, appointed Registrar in this Department, from 18th May 1899.

MUSEUM ASSISTANT.

T. R. BLYTH, deputed to Paris in charge of Geological Collections. Left Calcutta by B. I. S. N. Co.'s S.S. *Goorkha*, on 30th January 1900.

INSPECTOR OF MINES IN INDIA.

JAMES GRUNDY.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

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1900.

PART I.—HEAD-QUARTER NOTES.

Director's Tours.

During the twelve months under review, I made the following tours:—

(1) From the 7th June to the 5th July 1899 to the Madras Presidency to arrange for the survey work to be carried on during the field season 1899-1900.

(2) From the 5th February to the 20th March 1900 to the Central Provinces, Gujerat, Rajputana, and Sind in connection with an inquiry into the possibility of obtaining water by Artesian borings.

1.—MUSEUM AND LABORATORY.

Curator.

Mr. T. H. Holland took charge of the office of Curator on the 1st May 1899, relieving Mr. C S. Middlemiss. Mr. Holland reports on his duties during the past year as follows:—

Rearrangement of specimens in the show-cases.

With the limited amount of space available in the Museum it has been possible in the classified collection of minerals to exhibit only representative specimens of each type, the cases being altogether

too crowded to represent the known localities for each species. But in connection with the collection of economic minerals it has always been the aim of the department to make it fully representative of our knowledge concerning the occurrences in India of valuable minerals. With the numerous additions which have been made of late years it was found that the accommodation originally provided was rapidly becoming insufficient, and accordingly arrangements have now been made for extending the collection along the northern recess cases previously occupied by a set of foreign rock specimens. The classification originally adopted by Mr. Mallet has been retained, and with the additional accommodation the metalliferous ores, and minerals which are of value because of the base they contain, occupy the northern recesses, whilst the non-metallic products and materials, like mica and corundum, which are of value on account of their special physical properties, are exhibited in the southern recess cases. The cases containing these minerals have been cleaned throughout and the specimens completely labelled.

The collection of Indian rock-specimens occupying cases Nos. 37 to 80 in the centre of the gallery have now been arranged in the stratigraphical order adopted in the new edition of the Manual of Indian Geology. On account of petrological studies which have been made since the issue of the Manual, we are now able to indicate amongst the great complex of crystalline rocks certain formations which, though foliated in conformity with the gneisses around, are regarded as normal, though very ancient, intrusive, igneous rocks. The removal of these from the ordinary gneiss groups does not disturb the classification adopted by the older workers, for the residue of the crystalline schists, and, like somewhat similar formations found in other countries, they are retained side-by-side with the two main groups of schists, as they are also very old, and, in default of evidence to the contrary, may be grouped with the Archæan. The following are amongst such groups of igneous rocks which have been identified:—

(1) The elæolite-syenites, augite-syenites and associated corundiferous felspar rocks of the Coimbatore district.

(2) The ægirine-granites and augite-syenites of Salem district.

(3) Various gneissoid granites, like the so-called "dome gneiss" of Behar, the central granite of Coorg, etc.

(4) Pyroxene-granulites and granulites distinguished under the name "charnockite series."

(5) Anorthosites of Bengal and norites of Coorg.

(6) Various ancient basic pyroxenic dykes and lenticular masses partially or wholly changed to epidiorites.

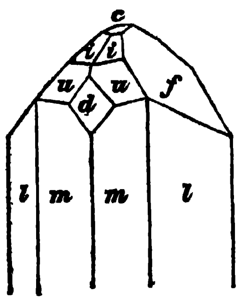
In conformity with the system adopted in the Manual the various Peninsular intrusives in the gneisses, which are young enough to have escaped foliation, are exhibited near the ancient rocks which they traverse. Of these, one case is devoted to the display of the mica-bearing pegmatites, and two others to the exhibition of various types of felsites, porphyries, basic dykes and peridotites, which are found as dykes and other intrusive masses in the gneisses.

Selections from the collection of foreign-rock-specimens have been arranged and labelled in 14 cases in the north-west room as illustrations of petrographical geology, the series of illustrations of physical geology being reserved to the remaining 10 cases in the same room.

The class, order and generic names have been completely renewed throughout the gallery of tertiary fossil vertebrates, and considerable progress made towards renovating the labels throughout the Museum.

Besides the collections made during the previous field season by the officers of the department, a number of interesting additions have been made during the year. Mr. H. H. Hayden obtained a series of specimens and photographs illustrating the manufacture of borax in Ladakh.

Amongst a series of river gravels from the Katha district sent by the Burma Government, several colourless topaz crystals were detected amongst other gem-stones. The discovery is of interest as the first-recorded occurrence of the mineral topaz in India or Burma. Amongst the fragments one was found with faces sufficiently well preserved for determination with the reflecting goniometer. The following forms, represented in the wood-cut, were found :—



m	(110)	prisms.
l	(120)	
f	(021)	brachydome.
i	(223)	pyramids.
u	(111)	
d	(201)	macrodome.
c	(001)	basal plane.

From Burma also we have received specimens of antimonial tetrahedrite, tin-stone and wolfram obtained in the Shan States, and pebbles of pure rutile obtained by Mr. C. M. P. Wright in the Katha district.

Mr. R. D. Oldham has presented the Department with an interesting collection of crystalline rocks collected in Ceylon whilst on furlough. They include, besides pyroxene-granulites, granulites and gneisses similar to those known in the southern districts of the Madras Presidency, specimens showing veins of graphite in a quartz-felspar rock, the moonstone in its matrix of pegmatite, and cipolin with a blue apatite (moroxite) similar to that occurring in the ruby-bearing limestone of Burma.

Meteorites.

A few additions have been made to the collection of meteorites by exchange; but the most interesting is a new meteoric iron found near Kodaikanal on the Palni Hills, Madura district, and acquired by purchase through the help of Mr. C. Michie Smith, Director of the Madras Observatories. This meteorite weighed about 35 lbs. when found, and was covered with a coat of rust due to its having, in all probability, been exposed for some time to the weather. There is no record of its fall, but a large meteor was seen eight years before to burst over the Pillar Rocks near Kodaikanal, and it is not unlikely that this "iron" fell at the time.

It is found to be composed almost entirely of nickeliferous iron, with included irregular mineral masses, measuring sometimes 10 mm. across. Crystal structures—imperfect Widmanstätten figures—are developed by etching the polished surface of the iron with dilute acid; but beyond these tests, which satisfactorily establish the meteoric origin of this iron, the specimen has not yet been examined in detail. The surface shows the "thumb-marks" characteristic of the siderites.

A certain amount of interest is attached to this "find" on account of the rarity of Indian meteoric irons. Although stony meteorites have been found in great numbers, only one other iron has been obtained in India, and that was seen to fall near Nidigullum (lat. 18° 41′ 20″; long. 83° 28′ 30″) in the Vizagapatam district on January 23rd, 1870. The Nidigullum meteorite[1] weighed 10 lbs. only, so the Kodaikanal meteorite, beside being only the second Indian "iron" recorded, is much the larger of the two.

[1] Proc., Asiatic Soc. Beng., 870, p. 64.

A considerable amount of time during the year was taken up in connection with preparations for the Paris Exhibition to which a collection of specimens, maps and photographs have been sent by this department. On account of the limited space placed at our disposal, selections only have been made from the material available for the purpose. These have been grouped in the gallery as follows:—

Paris Exhibition.

(1) A collection of rock-specimens from the Peninsula with photographs and drawings of rock-sections, illustrating the chief types of Archæan crystalline schists and the igneous rocks associated with, or intruded into, them.

(2) A collection of minerals of economic value, illustrating the resources in minerals used for ornamental purposes, corundum, mica, graphite and the principal natural compounds of borax, phosphorus, sulphur, strontium, barium, magnesium, aluminium, manganese, iron, titanium, molybdenum, tin, lead, antimony, arsenic, copper, and gold.

(3) A collection of various minerals, mostly presenting characters peculiar to India.

(4) A collection of Gondwana coals.

(5) A collection of striated and facetted boulders.

(6) A collection of specimens, maps and photographs illustrating the geology and resources of the Giridih coalfield as a type of the Gondwana coalfields of Bengal.

(7) A case containing specimens of the flexible sandstone obtained from the Punjab.

(8) A collection of iron-ores and native-made iron and steel, together with specimens of the products of the Barakar Iron Works which are conducted on European lines by the Bengal Iron and Steel Company. Photographs of the works and of Native iron and steel makers.

(9) A collection of specimens showing various forms of laterite kankar and other concretionary rocks.

(10) A collection of rock-salt and associated minerals from the Punjab.

(11) A collection of Burma petroleum and products artificially prepared therefrom by the Burma Oil Company.

(12) A collection of one-foot cubes of building stones and a series of slabs, carved screens and pillars made from rocks used for ornamental and building purposes.

(13) A collection of maps, diagrams and photographs grouped to illustrate certain points in the Geology of—

(*a*) the Indian Peninsula,

(*b*) the Himalayan region, and,

(*c*) the areas lying outside the Peninsula and the Himalayas.

(14) A collection of memoirs and manuals published by the Geological Survey of India and descriptive of the geological results obtained by the Department.

Several valuable specimens were contributed to the collection of exhibits by Mining Companies in India. The following are the principal contributors:—

Bengal Coal Coy., Ld.—Cubes of coal and specimens of coke from the Bengal fields.

East Indian Railway Coy., Ld.—Coal, coke rock-specimens and diagrams of the Giridih coalfield.

Chief Engineer, Central Provinces.—Coal from different seams in the Warora and Umaria collieries.

Hyderabad (Deccan) Coy., Ld.—Coal from the Singareni collieries.

Bengal Iron and Steel Coy., Ld.—Ore, fuel, and limestone used, and various pigs and articles of cast-iron manufactured, in the Barakar Iron-works.

Burma Oil Coy., Ld.—Various petroleums and manufactured by-products.

Messrs. Ambler & Co.—Various slates from the Kharakpur hills.

Mysore Geological Department.—Gneiss slabs and ornamental stones from Mysore State.

Commissioner of Coorg.—Cubes of Watekolli norite.

Vizianagram Mining Co.—Various manganese ores from the Kodur mines.

Messrs. F. F. Chrestien & Co.—"Books" of mica and sickle-dressed mica of various colours and grades.

Indian Mica Coy., Ld.—Various micas from the Bendi mines.

Messrs. C. A. Macdonald & Co.—Mica from the Koderma area, Hazaribagh district.

Messrs. Best & Co.—Mica from the Nellore district.

Commissioner of Northern India Salt Revenue.—Salt and associated minerals from different areas in the Punjab.

Madras Government.—Native-made iron and steel from the Salem, Trichinopoli and Malabar districts.

The following donations have been made to the Museum during the past year:—

Donation.	Presented by.
Auriferous quartz with altaite and chalcopyrite .	The Manager, Choukpazat Gold Mining Coy., Ld.
Sheets of muscovite, Tellabodu mica mines, Nellore district.	A. Subha Naidu.
Sheets of muscovite, Biradavole mica mines, Nellore district.	Messrs. Best & Co.
"Potato stone," Bankura district	Raja Sir Sourindro Mohan Tagore, Kt., C.I.E.
Specimens of serpentine and gabbro from stream bed entering Lamia Bay, Great Andaman Island.	Captain A. R. S. Anderson, I.M.S.
Galena from Raksi (23° 59′; 85° 1′), Hazaribagh district.	A. Gow Smith, Esq.
Slice of the Tonganoxie meteoric iron. Weight 140 grammes.	Professor H. A. Ward.
Specimens of mica with inclusions of garnet and apatite, Bendi, Hazaribagh district.	A. Mervyn Smith, Esq.
Specimens of apatite, garnet and "silvery" muscovite near Bendi, Hazaribagh district.	A. Mervyn Smith, Esq.
Specimens of corundum in felspar rock, garnets, twinned crystals of muscovite, microcline, chrysoberyl, blue apatite and graphic granite from the neighbourhood of Padyur and Karutapalaiyam, Coimbatore district.	Captain H. M. Campbell, R.A.
Selenite from near Kharagoda, Rann of Cutch .	H. G. Bulkley, Esq.
Quartz with epidote and cubes of limonite pseudomorphous after pyrite, from the Murbhanja State.	Babu Tinkari Choudhry.
Slab of fuchsite-quartzite from hills near Nemakallu, Bellary district.	Superintendent, Government Museum, Madras.
Rolled pebbles of rutile from Mohynui, Katha district, Burma.	C. M. P. Wright, Esq.

Donation.	Presented by.
Mud pellets which fell during a shower of rain in Daltonganj district, October 1899.	Meteorological Reporter to the Government of Bengal.
Blocks of Magnesite, Chalk Hills, Salem district .	Messrs. Arbuthnot & Co.
Triplite, Singar, Gaya district	H. M. Hannay, Esq.
Elæolite-Syenite from Girnar, Junagar . . .	Colonel J. M. Hunter, C.S.I.
Iron-pyrites from the main coal seam, Kuldiha colliery, Giridih coalfield.	E. Seymour Wood, Esq., F.G.S.
Topaz crystal, from tributary of the Ledaw-chaung, Katha district, Burma.	R. Clarke, Esq.
Specimens of moonstone in its pegmatite matrix; veins and disseminated scales of graphite in granite and quartz; cipolin with moroxite; pyroxene granulite; granulite; biotite gneiss; marble; calciphyre; pyroxenite; biotite rock and biotite sheets from various localities in Ceylon.	R. D. Oldham, Esqre., F. G. S., Geological Survey of India.

List of Assays and Examinations made in the Laboratory during the past year.

Substance and locality.	Sender.	Results of examination.
A specimen from the Sirohi State for determination.	Captain F. T. C. Hughes, I.S.C., Erinpura.	*Carbonaceous shale.* Composition :— Moisture . . 0·56 Volatile matter . 2·96 Fixed carbon . 8·94 Ash . . . 87·54 100·00 Does not coke. Ash, light-brown.
Three specimens from the Mahanadi River, Bhatgaon, Bilaspur district.	F. H. Smith, Esq., Deputy Superintendent, Geological Survey of India.	Calcareous shales with the following compositions:— | | A. | B. | C. | Insoluble in Hce. | 51·01 | 19·21 | 12·51 Fe_2O_3 and Al_2O_3. | 7·11 | 2·71 | 2·21 $CaCO_3$. | 36·27 | 76·09 | 84·13 $MgCO_3$ (by difference). | 5·61 | 1·99 | 1·15 | 100·00 | 100·00 | 100·00

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Specimen found in Central India.	The Reporter on Economic Products to the Government of India.	Asbestos.
Mineral occurring in the mica-bearing pegmatites, at Tallapad, Nellore district (No. $\frac{13}{539}$).	Dr. T. L. Walker, Assistant Superintendent, Geological Survey of India.	Automolite (zinc-alumina spinel); specific gravity, 4·586.
Specimen from the Kohat district.	R. N. Hodges, Esq., Kohat, Bannu Railway Survey.	Gypsum.
Mineral from the Mica-bearing pegmatites, Chaganam, Nellore district (No. $\frac{13}{539}$).	Dr. T.L. Walker, Geological Survey of India.	Columbite; specific gravity, 5·748.
Four specimens from the Henzada district.	Deputy Commissioner, Henzada, through the Director, Land Records, Burma, and Reporter on Economic Products.	1. *From Shandaung S. W. of Lemyethna.* Ordinary laterite. 2. *Three miles N. of Pethalet.* Impure steatite. 3. *Found lying above No. 2.* Nodule of impure serpentine. 4. *Eight miles W. of Kyauktaung.* Decomposed iron-pyrites.
Specimen from Upper Burma.	Reporter on Economic Products.	Graphite schist.
Specimen from the Gaya district.	Chevalier O. Ghilardi, Vice-Consul for Italy, Calcutta.	Triplite.
Two specimens examined for gold.	G. Barton-Groves, Esq., Deputy Postmaster-General, Rajputana.	1. Quartz with specular iron. 2. Quartz with copper pyrites. Both specimens contain traces of gold.
Specimens of yellow clay from Katni, Jabalpur district.	The Under Secretary to the Chief Commissioner, Central Provinces.	Fuller's Earth.
Specimen for determination.	R. H. Morton, sq., Mal P.O., Jalpaiguri.	Rock crystal.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Two specimens for determination.	Reporter on Economic Products.	Iron-pyrites. Quartz in clay slate.
Specimen from Bankipur	Do. do.	Talcose schist.
Specimen from Bannu, Punjab.	Do. do.	Coal with small quantities of pyrite.
Three specimens from the Duars.	Do. do.	1. Dolomitic limestone. 2. Calcareous tufa. 3. Air-slaked lime.
Four specimens for determination.	F.B. Manson, Esq., Officiating Conservator of Forests, Tenasserim Circle.	1. Quartz with pyrite in veins. 2. Quartz with vesicular pyrite and ferrous sulphate traces. 3. Iron pyrites. 4. Sand containing iron-pyrites, quartz, galena and schist fragments. The first two were found on assay to contain no gold.
Specimen said to be from Sikkim.	W. P. Masson, Esq., Darjeeling.	Coal, crushed and showing the usual characters of the Darjeeling Gondwana coal.
Two specimens from the Maw State of the Myelat in the southern Shan States, for gold.	M. Hunter, Esq., M.A., F.C.S., Chemical Examiner, Burma, Rangoon.	B. *Quartz.* Contains visible gold. C. *Quartz. Quantity received 1 lb. 6 oz.* Yielded on assay no gold.
Specimen of quartz with pyrites, for gold.	B. Houghton, Esq., C.S., Deputy Commissioner, Katha, Upper Burma.	*Quantity received 12½ oz.* Yielded on assay no gold.
Specimens found in the hills adjacent to Simla.	Sergeant W. Wren, His Excellency the Viceroy's Band, Simla.	Crystals of kyanite in sericite and chloritic schist.
Specimens of "calcareous cement" from Tavoy, Burma.	Geo. Watt, Esq., C.I.E., Reporter on Economic Products to the Government of India.	Cement found to contain much carbonate of lime and of very poor quality—structurally weak through, probably, use of imperfectly burnt lime.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Specimen from Hills near Nemakallu, Bellary.	Dr. Edgar Thurston, Superintendent, Government Museum, Madras.	Quartzite with fuchsite.
Specimen found on the banks of the Oubuikwin stream near Oubuikwin village, close to the Henzi basin.	F. B. Manson, Esq., Officiating Conservator of Forests, Tenasserim Circle, Rangoon	Pyritous sand with pebbles of tinstone (cassiterite).
Specimen picked out of the hill side at Simla.	A. Richards, Esq., Alliance Bank of Simla, Ld., Simla.	Pyrite.
Specimen from Burma.	Dr. Geo. Watt, Reporter on Economic Products to the Government of India.	Arsenolite (As_2O_3) with small quantities of Realgar (As S) and Orpiment (As_2 S_3). Sp. Gr. 3·69.
Seven Micro-sections of rocks collected during the season 1898-99 in Raipur, Kanker and Bustar.	P. N. Bose, Esq., B.Sc., F.G.S., Geological Survey of India.	Three slides of altered diabase, composed of augite partially changed to hornblende, and secondary minerals including quartz, lencoxene and epidote. One rock from Lakhimpuri, Kanker State, contained micro-pegmatite. Four slides of granitite-gneiss composed of quartz, orthoclase (microcline and micro-perthite), oligoclase, biotite, epidote, sphene, and zircon.
Specimen found in Kharagoda.	H. G. Bulkley, Esq., Assistant Collector of Salt Revenue, Kharagoda, Kathiawar.	Selenite.
Specimens from near Kangyam, Coimbatore district.	Capt. H. Monty Campbell, R.A.	1. Twinned crystals of muscovite, blue apatite, albite and microcline. 2 and 3. Corundum in felspar rock. 4. Garnets from old beryl mine. 5. Muscovite showing lines parallel to the pressure figure.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of Examination.
		6. Graphic granite. 7. Microcline. 8. Corundum. 9 Felspar with chrysoberyl and corundum.
Specimen from Ootacamund.	Capt. H. Monty Campbell, R.A.	Allophane.
A specimen of the dust which fell during a shower of rain at Simla on the 14th July 1899.	The Meteorological Reporter to the Government of India, Simla.	Contains, besides ordinary ferruginous clay, distinct traces of carbonate and phosphate of lime in a very finely divided state and agreeing chemically with dust from the Punjab plains.
Specimens found near Kendi, Hazaribagh district.	A. Mervyn-Smith, Esq.	Garnets, fresh and decomposed. Iron ore. Schorl. Apatite with quartz and felspar.
Specimens found in the Mawlu Township of the Katha district.	The Revenue Secretary to the Government of Burma, Rangoon.	Four packets mainly garnet. One packet contained, besides garnet, one small fragment of schorl, fragments of quartz, sapphire and 4 pieces of colourless topaz.
Specimen found in the southern Shan States.	Ditto ditto .	Antimonial tetrahedrite, composed of sulphide of antimony and copper with smaller quantities of arsenic, iron, zinc, lead and silver, also weathered products, carbonates of copper, oxides of antimony and ferruginous clay.
Six specimens from Kila Drosh, Chitral country.	Lieutenant-Colonel R. W. MacLeod, Commanding 29th Punjab Infantry, Kila Drosh, Chitral.	Nos. 1, 2, 3, and 5, serpentines with varying quantities of rhombohedral carbonates. No. 4 volcanic ash, decomposed. No. 6 vein quartz with copper ore (sulphide and carbonates).

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of Examination.
Specimens from the Maurbhanja State, Balasore.	Babu Tinkari Chowdhry, Maurbhanja, Balasore.	Limonite and hematite pseudomorphous after pyrite.
Two specimens for determination.	W. Pendlebury, Esq., Agent and Manager, H. H. the Nizam's Guaranteed State Railways Co., Limited, Secunderabad, Deccan.	1. Granite with pyrite filling cracks. Tested for gold without positive result. 2. Biotite-hornblende rock from segregation patch in the granite.
Specimen obtained from a bank recently raised above sea-level about 2 miles from Tagacherry off the coast at Quilon.	Dr. Edgar Thurston, Superintendent, Government Museum, Madras.	Foraminiferal and shell sand agglutinated into worm tubes.
Specimens from the Bendi area, Hazaribagh district.	A. Mervyn-Smith, Esq.	1. Melted lumps of metallic tin. 2. Scoriaceous "bloom" of tin and iron. 3. Hornblendic gneiss. 4. Pegmatite with purple garnet, etc. 5. Tourmaline with core of quartz.
Specimen said to have been procured from the Chota Nagpur Division.	Reporter on Economic Products to the Government of India.	Hematite sand with small quantities of magnetite.
Eight specimens from Chitral.	Lieutenant-Colonel R. W. MacLeod, Commanding 20th Punjab Infantry, Kila Drosh.	1 Buff-coloured marl. 2. Quartz impregnated with carbonates of copper, lime and magnesia. 3. Dolomitic veins in marl. 4. Mica-hornblende-pyroxene-peridotite approaching scyelite. 5. Silky schist with pyrite cubes. 6. Altered porphyrite. 7. Impure serpentine. 8. Alteration product of schist.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Specimen found in the Chanda district, Central Provinces.	A. E. Lowrie, Esq., Deputy Conservator of Forests, Chanda, Central Provinces.	Calcite crystals.
Specimen found in the Maurbhanja State, Balasore.	Tinkari Chowdhry, Maurbhanja, Balasore.	Slag.
One specimen for determination.	The Reporter on Economic Products to the Government of India, Calcutta.	Granular epidote.
Three specimens from Nagpur.	Ditto	Fuller's earth, 3 varieties.
Specimens from Mohyniu, Katha district, Upper Burma.	C. M. P. Wright, Esq., Choukpazat Gold Mining Co., Limited, Upper Burma.	Rolled pebbles of black rutile.
Specimen quarried near Gwalior for ornamental purposes, and four specimens from Malwa.	Colonel D. G. Pitcher, I. S. C., Department of Land Records, Gwalior State, Morar.	Block of sandstone, and 1. Basalt. 2. Quartzose fault-rock with limonite. 3. Garnetiferous mica-schist. 4. Sericite schist.
Two packets of gems from a tributary of the Ledawchaung, Katha district, Upper Burma.	The Deputy Commissioner of Katha, through the Secretary to the Financial Commissioner of Burma, Rangoon.	*1st Packet contained*— Rubies, sapphires, green tourmaline, zircon, topaz, garnet, spinel and quartz crystals. *2nd Packet*— Sapphires, green and black tourmaline, topaz, quartz, felspar, garnet, spinel and ruby.

List of Assays and Examinations made in the Laboratory during the past year—concld.

Substance and locality.	Sender.	Results of Examination.
Stones found in a well of the Byturni Bridge, Cuttack district.	E. Beckett, Esq., District Engineer, Bengal-Nagpur Railway, Jenapur, Cuttack.	Six pieces of glass and two of quartz.
Specimens from the Chandon Estate, 8 miles north of Baidyanath Junction, East Indian Railway.	Henry Bateson, Esq., Gillanders, Arbuthnot & Co., Calcutta.	1. Muscovite weathered and broken in books of 2″ to 3″. 2. Cerussite and minium. 3. and 4. Quartz crystals. 5. Small piece of pegmatite. 6. Tourmaline (schorl). 7. Garnets. 8. Coal.
Rock from the village of Hatipota, 4 miles east of Bilasipara, Goalpara district.	Engineer-in-Chief, Eastern Bengal State Railway, Calcutta.	Granitoid gneiss (binary granite) suitable for ordinary structural purposes.
Specimen from Koraput, Vizagapatam district.	Dr. T. L. Walker, M.A., Geological Survey of India.	Limonite.
Specimens from the Chandon Estate, 8 miles north of Baidyanath Junction, East Indian Railway.	Henry Bateson, Esq., Gillanders, Arbuthnot & Co., Calcutta.	1. Black tourmaline (schorl). 2. Coal (not obtained *in situ*). 3. Ilmenite. 4. Oxide and carbonate of lead. 5. Garnets.
Specimen from the Darjeeling district.	Pell & Co., Calcutta.	Yellow ochre.

MR. F. R. MALLET.
Langbeinite.

Mr. F. R. Mallet has continued to show his interest in the work of the department by the publication, since his retirement from the service, of researches bearing on the mineralogy of India. His latest work consists of an investigation of the mineral langbeinite, a double sulphate of potash

and magnesia, which occurs as a constituent of the deposit of potash salts discovered by Dr. H. Warth in the Mayo Salt Mines in 1873. The existence of the compound $K_2\ SO_4$, $2\ M_g\ SO_4$ as a definite mineral constituent of this deposit has now been established by Mr. Mallet, who has also prepared the mineral artificially by fusing together the two sulphates in proper proportions (*Min. Mag.*, Vol. XII, 1899, p. 159), and has extended his researches by artificially preparing a number of allied double sulphates of the general form $2\ M''\ SO_4$, $R'_2\ SO_4$ (*Trans. Chem. Soc.*, Vol. 77, 1900, p. 216).

2.—PALÆONTOLOGICAL WORK.

Collections.

A record of good work and actual progress has been established during the past year in this most important branch of the Survey, both in India and through our scientific helpers in Europe.

a. IN INDIA :—

DR. NOETLING on Miocene fossils of Burma.

The Palæontologist of the Department, Dr. Fritz Noetling, continued the description of the large collections from the miocene beds of Burma. This work has been already mentioned in the General Reports of 1898 and 1899; it is now finished and will be published in THE PALÆONTOLOGIA INDICA.

Dr Noetling has taken much trouble in dealing with this subject which, owing to the almost total absence of any literature of reference, was particularly intricate, and in order to arrive at a correct idea as to the true relationship of this fauna, he was obliged to compare the fossil specimens with their living relatives inhabiting the Indian Ocean. This necessitated of course a good deal of extra work, not generally connected with the study of fossils, but the results are very satisfactory, and Dr. Noetling's memoir will remain a standard work for the study of the tertiary fauna of India, particularly as he has indicated a new direction which researches of this kind should take in future. The main results are the following:

The living fauna of the Indian Ocean has partly descended from the fauna of the miocene period inasmuch as 30 per cent. of that fauna still exist in a living state. On the other hand, it seems certain that the fauna of the Indian Ocean contains a foreign element, the ancestors of which have not yet been found in a fossil state in India.

Dr. Noetling has carefully studied the relationship of the remaining 70 per cent. of the miocene fauna, which represents the "extinct" element of the fauna of the Indian Ocean.

He was able to distinguish four classes, *viz.*:—

(1) Species of which no relative, either living or fossil, could be traced.

(2) Species which show the closest relationship to species occurring in the eocene of France.

(3) Species which show the closest relationship to species living at present in the western province of the Pacific Ocean, but which do not occur in the Indian Ocean.

(4) Species which show a close relationship to species living at present in the Mediterranean.

Dr. Noetling thinks that the first group represents the "indigenous" element, that is to say, species which are closely related to such which occur in the older tertiaries. He states that this view has been fully confirmed by the study of the fossils collected by him in the eocene of Sind where he discovered numerous species identical with such included in the above group.

The second group which he calls "Gallic types" proves that an intimate connection must have existed between the eocene fauna of Europe and the miocene fauna of Burma. This connection can only be explained by the theory of a migration of species from west towards east which commenced with the eocene period, and lasted probably up to quite recent times. This theory is greatly supported by the occurrence of the third group, which he calls "Pacific types," the existence of which can only be explained under the supposition that towards the end of the miocene period the representatives of this group migrated further eastwards, while they died out in the region of the Indian Ocean. The above four groups are called "palæogene species" in opposition to the "neogene" species which are again subdivided into three groups. According to Dr. Noetling the fauna of the miocene of Burma would therefore be composed as follows:—

Palæogene species.	Indigenous types	36·2 %
	Gallic types	13·8 %
	Pacific types	18·6 %
	Mediterranean types	1·2 %
	Species not classified	0·6 %

Neogene species.	Identical species	11·4 %
	Sub-identical species	11·4 %
	Evolutionary species	4·8 %
	Species not classified	2·4 %

This fauna lived in a very shallow sea not exceeding 25 metre in depth, and as there are several fossiliferous horizons succeeding each other in vertical direction in a series measuring not less than 2,450 feet in thickness, the deposit of the miocene beds must have accumulated during a time of rapid subsidence.

A further and most interesting fact is the proof that the miocene of Burma does not share a single species in common with the miocene fauna of Europe, but exhibits a great similarity with the miocene of Java and Sumatra on one side and the fauna of the Gaj beds of western India on the other side.

The stratigraphical part of the memoir deals with the subdivision of the tertiaries in Burma in general, and the miocene of Burma in special, which is illustrated by a number of characteristic sections.

Dr. Noetling's memoir is not only very important from a purely scientific point of view, but it permits definite conclusions to be drawn with regard to the occurrence of petroleum and coal in Burma, which we now know to occur in the lower miocene only.

DR. F. NOETLING.
Permian and triassic fossils of the Salt Range.
Tertiary fauna of Sind.

During the last field season Dr. Noetling was on tour in the Salt Range and later in Sind, from which localities he has brought away a magnificent collection of fossils which will require much time to determine and describe. New light has been shed through these fossils on the relations of the permo-trias sections of the Salt Range, whilst the lower tertiary fossils of Sind will form one of the most important additions to our collections. This work, which was done during the last month or two with Mr. Vredenburg as assistant, is noticed in Part II of this Report.

DR. A. VON KRAFFT.
Triassic Fossils of the Himalayas.

The palæontological work accomplished by Dr. von Krafft during the cold season of 1899-1900, was of a two-fold nature. It consisted, first, of an examination of the very large collections obtained in Spiti by Mr. Hayden and himself during the summer of 1899, the results of which are embodied in Part III of this Report.

Secondly, a beginning was made with a systematic description of the recently made collections from the trias of the Himalayas.

These fossils were brought together in 1898 and 1899 by Messrs. Hayden and Dr. von Krafft from Spiti, and by Messrs. LaTouche, Smith and Walker from the Central Himalayas. They consist for the greater part of Cephalopoda and include representatives of the whole series of trias beds.

Of these collections the lower triassic ammonites have been almost completely determined. The following ammonites have been described :—

(1) Twenty-two new species, belonging to the genera *Meekoceras* (12 sp.), *Hedenstrœmia* (4 sp.), *Flemingites* (1 sp.), *Clypites* (1 sp.), *Pseudosageceras* (1 sp.), *Danubites* (1 sp.), *Ceratites* (1 sp.), *Lecanites* (1 sp.).

(2) Five previously described, but of which a revised description seemed desirable, *viz.* :—

Meekoceras hodgsoni, Dien.
,, *varahu*, Dien.
Hedenstrœmia mojsissovicsi, Dien.
Danubites kapila, Dien.
,, *nivalis*, Dien.

(3) Seven species, which previously had not been known to occur in the Himalayas, and had so far only been known either from the Salt Range or the lower triassic deposits of northern Siberia (mouth of the Olenek River), namely :—

Meekoceras cf. pulchrum, Waag. (Salt Range).
,, *aff radiosum*, Waag. (,, ,,).
Danubites radians, Waag. (Salt Range).
,, *rotula*, Waag. (,, ,,).
Proptychites ammonoides, Waag.
,, sp. aff. *latifimbriato*, Waag.

The chief stratigraphical result to which these palæontological researches have led, is, that the Otoceras beds of the Himalayas do not, as was hitherto believed, correspond to the beds at the base of the lower ceratite limestone of the Salt Range, but are equivalent to the ceratite marls and the lower ceratite sandstones, and very probably include also the lower ceratite limestone, while, on the

other hand the upper division of the lower trias of the Himalayas ("Subrobustus beds," Diener) does not correspond to the whole of the ceratite sandstones, but merely to the two upper divisions of the same, *viz.*, the Stachella beds and the Flemingites flemingiarus beds.

Mr. T. D. LaTouche.
Mr. F. H. Smith.
Dr. T. L. Walker.

During the rains of 1899 it was possible to depute three officers to the higher ranges of the Kumaon Himalayas to revise certain sections surveyed by me in former years, and also to collect more fossils in certain localities. A very large collection of fossils was made during these tours and is now awaiting description. The triassic collection made by Mr. Smith is particularly interesting and has been partly worked out by Dr. von Krafft; the older palæozoic fossils, chiefly found by Mr. LaTouche, will be sent to the British Museum, where older collections belonging to the Department are already awaiting description. Dr. Walker fell ill during his deputation, but not before a small, but interesting suite of fossils was obtained from the classic locality of Chitichun, north-east of the Milam passes.

Messrs. LaTouche, Middlemiss and Dutta.
Palæozoic fossils of Burma.

During the progress of surveys carried on in the Shan hills during the last field season, Messrs. LaTouche, Middlemiss and Dutta acquired a most interesting series of palæozoic fossils. Most of them are either of silurian or devonian age. Mr. Middlemiss discovered permian fossils in the southern Shan States, but his efforts to trace the locality into the Karenni country, where triassic fossils were supposed to have been found, failed entirely.

a. In Europe :—

The description of our fossil collections which have been entrusted to scientists in Europe, is progressing apace. The following gentlemen are at present at work on them :—

In England.

Dr. F. L. Kitchin, Geological Survey of England and Wales.	Jurassic *lamallibranchiata* of Cutch.

Dr. Kitchin will probably also undertake to describe the silurian fossils of the Himalayas.

In Austria.

PROF. DR. W. WAAGEN, University of Vienna.	Triassic fossils of the Salt Range.
PROF. DR. UHLIG, University of Prague.	Jurassic fossils of Himalayas.
DR. F. KOSSMAT, K. K. Geologische Reichsaustalt.	Cretaceous fossils of Assam.

In France.

PROF. R. ZEILLER, Ecole Nationale Supérieure des Mines, Paris.	Gondwana fossils.

DR. WAAGEN.

It is with the utmost regret that I have to record the death on the 24th March last in the 59th year of his age of Dr. Wilhelm Waagen, Professor of Palæontology at the University of Vienna, which took place after a lingering illness of several years' duration. Dr. Waagen was appointed to the Department in December 1870 and he had to retire on the 25th August 1875 in consequence of illness contracted during the progress of his researches in India. He was one of our oldest friends and fellow-workers and was almost up to the very last employed in describing the fossils of the Salt Range, which work has been left unfinished. Although later research has added much to our knowledge of the distribution and character of the permian and triassic faunæ of India and has in a measure contradicted some of the results arrived at by Dr. Waagen, it may still be said that this great palæontologist's work has laid the foundation to our more advanced knowledge, and that the enthusiasm and industry which Waagen brought to bear upon Indian palæontology will be greatly missed by us all.

PROFESSOR E. SUESS.

The most responsible duties in connection with the direction of the palæontological work carried on in Austria for the Department, and the auditing of the

disbursements on behalf of the same, has been ably and generously conducted by Professor E. Suess during the year under report, as it has been done by him for many years past.

3.—PUBLICATIONS.

The following publications were issued during the past twelve months :—

General Report. General Report on the work carried on by the Geological Survey of India from the 1st April 1898 to the 31st March 1899.

Memoirs. Memoirs, Volume XXIX, Report on the great Earthquake of the 12th June 1897 by R. D. Oldham.

Palæontologia Indica.—

Palæontologia Indica. Series XV, Himalayan fossils. Vol. I, Part 2.—Anthracolithic fossils of Kashmir and Spiti by Dr. Carl Diener.

Series XV, Himalayan fossils. Vol. III, Part 1.—Upper Triassic Cephalopoda Faunæ of the Himalayas by Dr. Edmund Mojsisovics.

New Series, Vol. I. No. 1.—The Cambrian fauna of the Eastern Salt Range by Dr. K. Redlich.

New Series, Vol. I. No. 2.—Notes on the Morphology of the Pelecypoda by Dr. F. Noetling.

Reports of the Inspector of Mines. Mr. Grundy, the Inspector of Mines in India, sent in the following reports which were published during 1899-1900 :—

1. Report on the Inspection of Mines in India, for the year ending 31st December 1898.

2. Report on the Inspection of the Coal-mines belonging to the Assam Railways and Trading Company, Limited.

3. Report on the Inspection of the Coal-mines in the Sor range of Hills near Quetta and at Mach.

Library.—The additions to the library during the year 1899-1900 amount to 1,890 Volumes, of which 1,185 were acquired by presentation and 705 by purchase. A detailed list of acquisitions is given in Appendix I.

Personnel.

Notification by the Government of India published in the "Gazette of India," dated 6th May 1899, Part I.—Leave.

Department.	Number of order and date	Name of Officer.	Nature of leave	With effect from	Date of return.	REMARKS.
Revenue and Agricultural Department.	Notification No 1404-50-2, dated 5th May 1899.	R D Oldham, Superintendent, Geological Survey.	Furlough for one year and 6 months	11th July 1899	...	Availed of subsidiary leave from 6th to 10th July 1899.

Notifications by the Geological Survey of India published in the "Gazette of India," Part II—Leave.

Department.	Number of order and date	Name of Officer.	Nature of leave	With effect from	Date of return	REMARKS.
Geological Survey of India.	Notification No 414, dated 28th April 1899.	P. N. Bose, Deputy Superintendent, Geological Survey.	Privilege leave for 1 month and 15 days.	15th May 1899.	30th June 1899.	*Gazette of India* dated 6th May 1899.
Ditto .	Notification No 249, dated 13th March 1900.	T. L. Walker, Assistant Superintendent, Geological Survey.	Privilege leave for 28 days	17th April 1900 or subsequent date.	...	Availed on 19th April 1900. *Gazette of India*, dated 24th March 1900.
Ditto .	Notification No 252, dated 13th March 1900.	D La Touche, Superintendent, Geological Survey.	Privilege leave for 3 months	15th April 1900 or subsequent date.	...	

Notifications by the Government of India published in the "Gazette of India," Part I—Appointments, Confirmation, Promotion, Reversion and Retirement.

Department.	No of order and date.	Name of Officer.	From	To	Nature of appointment, etc	With effect from	REMARKS.
Revenue and Agricultural Department	Notification No 1533-56 2, dated 12th May 1899.	T. H. Holland	Deputy Superintendent, Geological Survey	Curator, Geological Museum and Laboratory.	Substantive, permanent.	1st May 1899.	*Gazette of India*, dated 13th May 1899.
Ditto .	Notification No 2681-50-8, dated 12th August 1899.	Ditto .	Ditto .	Superintendent, Geological Survey.	Substantive, temporary.	6th July 1899.	*Gazette of India*, 12th Aug. 1899.
Ditto .	Ditto .	H H. Hayden	Assistant Superintendent, Geological Survey.	Deputy Superintendent, Geological Survey.	Ditto .	Ditto .	
Ditto .	Letter No 1675-61-2, dated 22nd May 1899.	T. L. Walker .	Ditto .	... ..	Substantive, permanent.	8th May 1899.	Confirmed.
Ditto .	Notification No. 3640-81-4, dated 13th Oct. 1899	G. A. Stonier .	Mining Special ist, Geological Survey.	.. ..	Substantive, temporary for 5 years.	4th October 1899.	*Gazette of India*, dated 4th Oct. 1899.
Ditto .	Notification No. 3873 81-10, dated 10th Nov. 1899	G. F. Reader .	Coal Specialist, Geological Survey.	......	Ditto .	1st November 1899.	*Gazette of India*, dated 11th Nov. 1899.
Ditto .	Notification No. 1300, dated 11th April 1900.	F. H. Hatch .	Gold Mining Expert, Geological Survey.	. . ..	Substantive, temporary for one year.	31st March 1900.	*Gazette of India*, dated 14th Apl. 1900.

Part II.—Field Parties.

Distribution of Officers.

During the year ending 31st March 1900 the officers of the Department were distributed as follows :—

Mr. R. D. Oldham . . Head-quarters till 5th July 1899; then furlough for 18 months.

SUPERINTENDENTS.

Mr. T. H. D. LaTouche . Head-quarters till 29th June 1899; Kumaon Himalayas till 1st October; at Delhi with Austrian Leonid Expedition during October; left head-quarters on the 26th November 1899 for the northern Shan States, Burma.

" C. S. Middlemiss . Head-quarters till 26th November 1899; then southern Shan States and Karenni country, Burma.

DEPUTY SUPERINTENDENTS.

Mr. P. N. Bose . . Head-quarters till 14th October 1899; then Central Provinces.

" T. H. Holland . . Head-quarters; in charge of Museum and Laboratory.

" P. N. Dutta . . Head-quarters till 3rd November 1899; then northern Shan States, Burma.

" F. H. Smith . . Head-quarters till 24th June 1899; Kumaon Himalayas till 14th October; then Ganjam, Madras Presidency.

ASSISTANT SUPERINTENDENTS.

Mr. H. H. Hayden . . Spiti Himalayas till 4th November 1899; then Wynaad, Madras Presidency.

" E. Vredenburg . . Baluchistan till 7th July 1899; head-quarters till January 1900, and then Punjab and Sind.

" Th. L. Walker . . Head-quarters till 24th June 1899; Kumaon Himalayas till 24th September, and then Vizagapatam, Madras Presidency.

Dr. A. v. Krafft . Spiti Himalayas till 4th November 1899; then head-quarters.

PALÆONTOLOGIST.	
Dr. F. Noetling .	. Head-quarters till 11th September 1899; then Punjab and Sind.
MINING SPECIALISTS.	
Mr. G. A. Stonier .	. Left head-quarters 17th November 1899 for the Wuntho district, Burma.
" G. F. Reader .	. Left head-quarters on the 10th November 1899 for the coal-fields of Rampur and Baghelkand.
SUB-ASSISTANTS.	
Lala Hira Lal .	. Head-quarters till 10th November 1899; with Mr. Reader in Baghelkand.
" Kishen Singh .	. Head-quarters till 17th November 1899; then with Mr. Stonier in Burma.
MUSEUM ASSISTANT.	
Mr. T. R. Blyth .	. At head-quarters till 29th January 1900; then proceeded on deputation to Paris in charge of exhibits.

Division of work.—The surveys were again divided as far as practicable into purely economic and scientific inquiries.

A.—Economic Inquiries.

1. GOLD.

Since the publication of Vol. III of the Manual of the Geology of India in 1881, gold mining in India has become an important industry, and the most sceptic persons must have become convinced that with proper management and economy many of our gold ores might be exploited to great advantage. At the present time, when owing to the introduction of metallurgical processes, quite unknown not long ago, it has become possible to work exceedingly low grade ores profitably, it is of great importance to study the question in all its bearings, and it has therefore been decided that full reports be drawn up on the mode of occurrence and nature of the auriferous rocks of the most important localities in India.

The most important areas in this respect are Burma and southern India; the work in Burma has been put in charge of Mr. G. A. Stonier, whilst Mr. H. H. Hayden has begun the inquiry in the Wynaad. Both have given (see Part III) preliminary accounts of their surveys, which will be continued duing the greater part of next year (1900-1901). The well-known expert in gold mining, Dr. F. H. Hatch, joined the staff of the Department on the 31st March of this year and will conjointly with the officers named above, continue the study of gold in India, and the result of this joint inquiry will then be published as part 3 of the Manual of the Geology of India.

Burma.

MR. G. A. STONIER.
LALA KISHEN SINGH.

Investigations were practically confined to the Wuntho district only, and a preliminary report on the results of this season's work is given in Part III. The district is evidently fairly well provided with auriferous reefs, though up to date all the leaders and reefs which have been examined were very limited in dimensions. There is no doubt of the presence of gold in paying quantities, whilst in some cases the reefs may even be called rich, but there remains doubt whether there is sufficient ore to repay working it on a large scale, which alone would ensure commercial success. Towards the end of March Mr. Stonier came across what appears to be a promising quartz-reef near Baumark, which runs to 9 dwts. over a width of 9 inches. He is now engaged in testing the extent of the reef.

Wynaad.

MR. H. H. HAYDEN.

A preliminary examination of the more important reefs of South and South-East Wynaad was carried out during the months of November to March of last year, a short report on which will be found in Part III. This survey will be continued on a larger scale during the next year by Mr. Hayden and Dr. F. H. Hatch. The results obtained by Mr. Hayden during his preliminary inquiry "tend to show that the majority of the reefs are probably too poor in gold to offer any prospects of remunerative working, yet it is possible that one or two may prove sufficiently rich to justify mining operations, provided they are carried on judiciously and under strictly expert supervision."

2. COAL.

Coal in Bikanir.

I have had occasion to re-visit Bikanir on my late tour in Rajputana and have ascertained that the question of the coal-field of Palana, referred to in my General Report of last year (p. 33), stands now practically as it did then. A good deal further development of the known seam has taken place at the same locality, but no borings have been conducted and it is unknown whether there are other seams below the one worked, and in what direction and to what distances the field extends. The Durbar had been advised by the State Engineer that the actual "proving" of the field is unnecessary, as, so I am told, sufficient coal is actually in sight for probable requirements on the Jodhpur-Bikanir Railway for a space of 15 years.

I still am of opinion that the field should be proved both vertically and horizontally; the position of it, midway as it will be between the North-Western, East Indian and Bombay Railway systems. marks it as one of the most important coal localities of India.

Rampur and Sohagpur coal-fields.

Mr. G. F. Reader, the coal-specialist of the department, examined at some length the coal-fields of Rampur (Eeb-river) and of Sohagpur, somewhat detailed reports on which are published in Part III of this Report.

Mr. Reader comes to the conclusion that as regards the Rampur field, further action should be directed towards the immediate exploitation of the "*Eeb coal seam*" and the completion of bore-hole No. 4 (K^4 of map) down to the Talchirs.

In the Sohagpur coal-field Mr. Reader finds that out of seven seams two (the Sabo and Amlei-Bokahi), are of workable thickness and very fair quality.

3. LANDSLIP AT DARJEELING.

MR. HOLLAND.

For three weeks during last October Mr. T. H. Holland's services were placed at the disposal of the Bengal Government to advise the Committee "appointed to inspect the buildings, roads and drains in and round the town of Darjeeling after the disaster of the 24th September 1899, ... and to suggest measures ...... to prevent the occurrence of landslips in Darjeeling in the future......." The general

conclusions of the Committee and reports of the Sub-Committees were published together with the thanks of the Local Government, in the *Calcutta Gazette* of the 7th December last. The numerous and destructive landslips were, it appears, confined to the soil-cap covering the gneissose formation which forms the Darjeeling ridge, and their immediate cause was satisfactorily traced to the excessive rainfall which, following an unusually heavy monsoon, deluged Darjeeling on the two days preceding the disaster.

The details of the Committee's lengthy report are purely of local interest but their conclusions as to the conditions for the development of soil-cap slips being in general agreement with the principles outlined in Mr. Holland's report on Naini Tal. I should like to endorse the following remarks for the beneficial warning of authorities in other hill stations which have hitherto escaped the punishments which have been meted out to Naini Tal and Darjeeling:—"Although it is true that the cause of slips recently examined (in Darjeeling) can be immediately traced to the heavy rain of September 24th—25th, it must not be forgotten—and this is a lesson of permanent value to all hill stations—that the necessary facilities have been in the course of gradual development for many years. The soil-cap is the direct product of the atmospheric decomposition of the rocks, and through the action of percolating meteoric waters is in process of continual growth at the superficial expense of the latter. The removal of soil from the surface by the mechanical action of running water, and the simultaneous addition of decomposition products below the sub-soil by the chemical activity of percolating water are not concurrently compensatory in slopes covered with vegetation: there is a balance in favour of the latter process which is periodically restored by slips from the surface. The formation of a soil-cap does not in itself contribute to an increase in the surface slope, but its removal from the foot of a slope by streams, which there acquire a greater erosive activity through increased velocity and volume, increases the average slope of the hillside....... The increase in the angle of a slope by the undermining action of a river is supplemented by the slow process of creep which proceeds step-fashion in every inclined soil-cap with the regular succession of wet and dry seasons. The expansion which follows the saturation of a soil-cap during each monsoon naturally takes place in the direction of least resistance, which is down the hillside. The desiccation which follows in the succeeding dry season

merely makes a pause in this movement—not a return to original conditions. Such a ratchet-and-paul kind of creep downwards and outwards proceeds until the conditions of stability are exceeded, and a landslip occurs to restore equilibrium. It is delusive, therefore, to suppose that, because a slope has apparently withstood the action of twenty monsoons, the absence of accident is an index to its stability and an insurance against danger in the twenty-first wet season. On the contrary, in a steep earth slope unprotected by artificial means, every monsoon brings it nearer to the inevitable landslip, and the more perfect appreciation of this fact by the authorities in our hill stations will help to guard against the constant, but fatal, tendency there always appears to be to repose confidence in a slope which has not by chance been the scene of an accident for a generation." Although this warning would not be applicable in the case of slopes on massive dolomite, as in parts of Mussoorie and Naini Tal, or on quartzite, as in parts of Simla, most of the Himalayan stations include slate and shale formations, or are covered with thick soil-caps which should never be allowed to exceed the angles of safety which have been determined for different degrees of saturation.

4. IRRIGATION.

Bhavani dam.

In Part III I give Mr. T. H. Holland's report on the site of the Bhavani dam. This note, referred to in my last Report, has since been published by the Madras Government, who have also recorded their thanks for Mr. Holland's services on the Committee appointed to investigate the Bhavani project.

Artesian water-supply.

During February and March I visited certain portions of the Central Provinces, Gujerat and Rajputana to ascertain, if possible, the chances of increasing the existing water-supply by means of artesian borings. Public attention had been directed to these means of alleviating the chances of famines in India, and in some measure it had been insinuated that Government neglected its duties by not resorting more frequently to artesian well-sinking in certain districts in India. That this is not so is shown by the immense mass of official papers on the subject, which I am directed to notice in a compilation on the subject about to be published. Actual attempts had been made to sink

artesian wells in different parts of India, but it must be owned, with indifferent success in most cases. Practically the only instance in which a water-supply has been thus obtained within British India, is the one afforded by the wells in the Quetta District, which are a decided success. It must be borne in mind that for purposes of finding artesian water the Peninsula of India may be divided into three great areas: (1) The Indo-Gangetic plains, (2) The Peninsula proper lying south of the Ganges alluvium, and (3) portions of the tertiary plains of the Rajputana desert, Gujerat and Sind.

1. The Indo-Gangetic plains are mostly formed of immense thicknesses of alluvial deposits in which artesian conditions seem to be absent. The deposits are probably of such thickness that it would be hopeless to try and penetrate the same down to the water-level. Borings have been made down to 1,800 feet thickness without meeting with any other but soft sands and sandstones through which water passes without let or hindrance. From the character of the beds where seen near the margins of the basin, it seems that the same character of permeability attaches to the entire immense thickness of this alluvium, which may be upwards of 20,000 feet.

2. The peninsula proper south of this last area consists mostly of either igneous and schistose rocks overlaid by systems of old palæozoic formations and great sheets of basic eruptive rocks (Deccan trap). These rocks, although in some measure absorbent and water-retaining, offer such poor chances of finding artesian conditions, that it would in most cases be a waste of time and money to attempt boring for artesian water.

3. In Rajputana, Gujerat and Sind conditions are somewhat different. There we find tertiary (eocene and miocene) marine beds spread over a considerable area, lying within well-defined basins or forming wide-spread, gently sloping, almost undisturbed deposits. It is probable that in the greater portion of the Rajputana desert these deposits may be found below the recent accumulations of sands and alluvial formations. In that part of Gujerat forming the drainage basins of the Gulfs of Cutch and Cambay, and also in parts of Sind the conditions are similar, and as a matter of fact a good supply of water is met within moderate depths from the surface within the tertiary beds. As the latter, particularly the upper nummulitic limestones, contain strings and layers of salt, it follows that the water of that horizon is generally brackish.

At ordinary times this water, although to some degree always

brackish, is used for domestic purposes and irrigation by the people of Rajputana and Gujerat, but during periods of drought the supply diminishes and then the water becomes almost brine and is useless alike for domestic and agricultural purposes. Attempts have been made at different times, as much as sixty and more years ago, to sink deep wells and artesian borings at several places in Gujerat, but the results were generally disappointing. The water obtained was found to be generally brackish; in one or two bore-holes it rose to within a few feet of the surface, but true artesian conditions have not been met with. It is true that none of these borings exceeded a few hundred feet, and it is difficult to form any workable deductions from the attempts.

When travelling in Gujerat and Kathiawar recently, I satisfied myself that there is no difficulty in obtaining plenty of water, even during the present season of drought, in places such as the vast plains of Gujerat, south and south-west of Ahmedabad. The natives have sunk a number of new wells at several places in that area and find water, only slightly brackish, within 40 to 50 feet from the surface. This water collects within the upper tertiary (miocene) beds, and it is probable that there are several well-defined horizons of such water. The tertiary deposits are underlaid in Gujerat by cretaceous rocks, which may be seen to outcrop along the borders of Kathiawar and Gujerat from under the traps which cover the greater part of the cretaceous beds. As far as these latter may be seen, they consist of dark-brown sandstones overlaid by light-coloured impure calcareous sandstones and marls. The latter act more or less as an impervious layer, whilst the porous brown sandstones beneath contain a good supply of water. It may be observed that wherever the upper marls have been removed by quarrying (near Wadwan for instance) the water contained in the sandstones below rises rapidly to the surface. Although slightly brackish, it is fit for domestic use.

It appears probable that these conditions will be found to prevail over a considerable part of Gujerat, and it may be, also in Rajputana, and I have therefore decided that it would be advisable to make a trial boring somewhere in the neighbourhood of Wadwan, this boring to be brought down to at least 1,000 feet or until the brown cretaceous sandstone is reached. There is some hope that the water reached in that horizon may then rise to the surface. Similar arguments may be urged in favour of certain localities in Rajputana, and I believe the Jodhpur Durbar has accepted my advice and will sink a deep boring between the Luni river and Balmer with

the double purpose of finding an artesian supply of water and to ascertain also, whether the eocene coal seams of Bikanir are repeated within the tertiaries which most probably underlie the recent deposits near Balmir.

B.—Geological Surveys.

1. BURMA.

MR. T. H. D. LATOUCHE.
MR. C. S. MIDDLEMISS.
MR. P. N. DUTTA.

During the season 1890 to 1891, Dr. Noetling made a geological traverse through the northern Shan States; since then the topographical maps of the latter have been much improved upon and it was therefore decided to carry out a more systematic geological survey of the Shan States of Burma and a traverse of the adjoining Karenni country. Messrs. LaTouche and Dutta worked along the section between Mandalay and the Kunlon Ferry of the Salween, whilst Mr. Middlemiss conducted a rapid traverse through the southern Shan States and the Karenni hills. The results obtained are exceedingly interesting; in the northern Shan States some additions were made to the geological notes on the country given by Dr. F. Noetling [1] and some fossils were collected which await description.

The results are embodied in progress reports in Part III of this Report; Mr. LaTouche comes to the following conclusions:—

"The formations met with along the route traversed by me, that is, the railway line under construction between Mandalay and the Kunlon Ferry, are the following, in descending order:—

List of Formations.

No.	Period.	Description of beds.	Local Name.
11	Recent . .	Valley gravels and alluvial deposits with numerous land and fresh-water shells. Older gravels and boulder beds. Red and yellow clays, often of great thickness, and sometimes consolidated by the infiltration of carbonate of lime into a hard rock containing land and freshwater shells. Similar clays hardened by infiltration of iron oxide, laterite, occasionally sufficiently rich to be used as an ore of iron.	

[1] Records, G. S. I., Vol. XXIII, p. 78, and XXIV, pp. 99, 119, 125.

List of Formations—(concluded).

No.	Period.	Description of beds.	Local Name.
10	Tertiary	White and yellowish sandstones with grey and brown clays and coal seams.	
9	Devonian?	Red and brown sandstones with numerous bands of red clay and shale. Few fossils.	Namyao beds.
8		Grey and olive shales with concretionary masses of dark blue limestone. Very fossiliferous.	Kyinsi beds.
7	Upper Silurian?	Thick beds of limestone generally siliceous, or calcareous sandstone, white or grey colours with subordinate bands of argillaceous shale or fuller's earth The shales contain many fossils.	Maymyo limestone.
6	Upper Silurian	Black calcareous shales with bands of hard black or dark grey limestone. *Graptolites*, etc.	Zebingyi beds.
5		Soft yellow sandy shales and sandstones with nodular beds of limestone. *Trilobites*, etc.	
4	Lower Silurian	Grey and olive green shales and limestones weathering into soft sandy shales. Many fossils.	Naung Kungyi beds
3		Flaggy limestones separated by bands of shale or clay, occasionally carbonaceous. *Orthoceras*, etc.	Myaungbaw beds.
2	Lower Silurian	Dark red calcareous shales with *Echinosphærites Kingi* and fragments of crinoids.	Red crinoid beds (Pyinthu beds, Nœtling).
1		Massive and flaggy limestones traversed by numerous veins of calcite.	Sedaw limestone. (Mandalay limestone, Nœtling.)

These beds seem to form a conformable sequence, but as each sub-division from the red sandstones downwards, has been greatly crushed, folded, and faulted and the dips often vary considerably both

in direction and amount within a space of a few yards, and, moreover, this line of contact between any two formations is generally concealed, it is impossible at present to say whether there is any unconformability or not. No mesozic formations were met with.

Generally speaking there is a distinct zonal arrangement of the different formations, the oldest occurring along the western edge of the hills ; while as we proceed eastwards newer formations are successively crossed. The general strike is between N.N.E. and E.N.E. but it varies greatly within short distances. This is also the general direction of the route taken, so that it often ran for several miles on one and the same formation.

The most interesting of the new formations discovered are the black graptolite shales with the underlying trilobite beds of the Zelingyi beds (Nos. 5 and 6). In the former *graptolites* are very numerous, often matted together on the surface of the layers. They appear to belong entirely to the monoprionidian order, no double forms being met with. They are associated with large numbers of another upper silurian fossil, closely resembling, if not identical with, *Tentaculites elegans* (Barr.) ; in fact the figures of this fossil in Barrande's Silurian system of Bohemia, Vol. III., pl. 14, might have been drawn from one of the Zelingyi shales. The *trilobites* are not so easily identified, being all fragmentary, but one or two specimens of heads are almost certainly those of *Eucrinurus punctatus. Fenestella retiformis* is also very common in these beds in one locality. The graptolite and trilobite beds are well seen in the railway cuttings on either side of Zebingyi Railway Station.

The shales and limestones of the Naungkangyi beds (No. 4) contain large numbers of casts of *Orthis* and *Strophomena.* Associated with these are numerous plates of a small cystirlean closely resembling *Mimocystitis Bohemicus* (Barr.) figured in Vol. VII, pl. 28, of Barrande's Silurian system of Bohemia. These belong to his stage D_2, corresponding to the Bala or Caradoc stages of Great Britain. These beds are well exposed in the Goktei gorge between the 84th and 86th miles on the cart-road. They also occur in the low hills about two miles north of Maymyo.

The white siliceous limestones (No. 7) are the most widespread formation found along the route. They extend from near Thondaung (vv aboye) station about eight miles west of Maymyo, almost without a break to the Salween, a distance of nearly 200 miles. The

only fossils they contain are the casts of small gastropods and a bivalve resembling *Pterinea*, but some shales found at Wetwun, twelve miles east of Maymyo, and again on the railway two miles north of Gokteik station, contain a fair number of fossils, which await identification, and are probably interstratified with these limestones. The latter form the precipitous cliffs on either side of the Gokteik gorge and about Lashio.

(No. 8.) A highly fossiliferous band of shales is found overlying the white limestone, but the fossils from it have not yet been specifically determined. They contain a small *Conocardium* and numerous specimens of *Pecten*, also a small gastropod, perhaps a *Murchisonia*. They may be of Devonian age. These were found in two localities: first near the village of Kyankyau, at the 73rd mile on the cart-road, and again near Kyinsi, from which village I have named the stage, at the 123rd mile. These beds occur at the base of a great thickness of red sandstones and shales (No. 9) which are especially well seen in the railway cuttings along the valley of the Mamyao or Lashio river. Here I found a few fossils in them, but all in a very fragmentary condition."

Southern Shan States and Karenni.

Mr. Middlemiss arrived at his working-ground in the southern Shan States on the 7th December, and he left it to return to head-quarters on the 4th April 1900.

Between those dates he was engaged in making a set of preliminary geological traverses through parts of the southern Shan States and Karenni, the main object being to cover as much ground as rapidly as possible in the time available.

Except for a brief tour by the late Mr. E. J. Jones in 1887, undertaken for economical investigations, the country was quite unknown in all details of its structure and stratigraphy. Mr. Middlemiss crossed the southern Shan States from Thazi as far east as Nongsewik (Long. 97° 45'). He then returned to Thamakan, and after working north for a short distance along the plateau, took a southerly direction to Loikaw in Karenni. From that point he carried a second cross-section through Karenni from the Salween river westwards to the plains again. The tour involved much hard and continuous marching.

The whole expanse of the country traversed was found to be an elevated plateau complicated by E.-W. crumplings of the strata

and so giving rise to N.-S. hill ranges with longitudinal valleys between. The rocks naturally group themselves into N.-S. longitudinal strike-zones of different composition. Mr. Middlemiss recognizes the following: (1) a gneissic and metamorphic zone ronting the Irrawaddy plain; (2) a great limestone zone, occupying the greater part of the plateau proper; (3) a purple sandstone zone, occurring along certain lines in zone (2) and inlaid with it, as it were; and (4) a zone of very young (subrecent to uppermost Siwalik) conglomerates, sands and loams, hardly disturbed at all, and occupying in the form of long strips certain of the broad flowing valleys of the plateau.

The gneissic and metamorphic zone consist of mixed hornblendic and micaceous gneisses, resembling those of South India, with veins of intrusive granite, also of quartzites, black slates, and schistose slates.

The limestones are the most characteristic rock of the plateau, and are dark or light grey in colour, frequently much brecciated and interbanded with many shales and marls.

It is unfortunate that no recognizable fossils were found by Mr. Middlemiss except in the case of certain bands of shaly limestone and marls in the hills between Hopông and Möng Pawn. In the latter (well-exposed along the Government cart-road) sufficiently good specimens were obtained to show that they are of middle Productus limestone age (permian). They are, therefore, probably a northern continuation of the Moulmein limestone.

The purple sandstone zone with its shales, coarse conglomerates, and coal beds, is thought to be younger than the neighbouring limestones. At the same time it has many points of resemblance to similar rocks east of Thibaw found by Messrs. La Touche and Datta in the northern Shan States.

Owing to dense jungle in places, to absence of good sections (except along the cart-road), and to the nature of massive limestone rocks, to weather into slopes of structureless blocks, Mr. Middlemiss found that his rapid survey does not warrant him in attempting to put in their normal order either the rock zones themselves, or their several component rock bands. It would at present be impossible to exhibit them in a generalized section showing the relative age and sequence of each; but it seems probable that their order in the section is not a simple one due to mere gentle undulation of the strata.

During his tour Mr. Middlemiss visited and examined some lead, silver, and copper mines near Bawzaing and Myinkyardo; some coal near Inwun, and lignite at several points in the Thamakan plateau. He also visited the "green-stone" tract on the Salween river near Namon, and found the stone (which is being collected as gems) to be green tourmaline with crystalline marble as matrix.

2. MADRAS PRESIDENCY.

MR. F. H SMITH. *Ganjam.*

During the season of 1899-1900 Mr. Smith was at work for five months during which time he reconnoitred an area of some 7,500 square miles, comprising the whole of the Ganjam district, except a small tract to the extreme south round Chicacole and Parlakimedi, which had already been mapped by the late Mr. Fedden of this Department.

Rocks.

The whole country is composed of two classes of rocks. By far the greater area is of crystalline igneous rock, into which bands of metamorphosed schist are folded. No unaltered sedimentary rocks are met with, but considerable areas are covered, and some of the hills are capped with laterite.

Crystalline igneous.

The foundation of the whole of the Ganjam district is a somewhat complex mass of rocks of igneous origin. By far the greater part consists of garnetiferous granitic rocks or leptynites, of every variety of texture, and of slightly varying composition, locally extremely crushed and foliated. Associated with these and interbanded with them is a series of pyroxene-bearing rocks—charnockites which pass gradually from acid forms to the more basic. The latter only occupy very limited areas, but the more acid pyroxene rocks, which are also garnetiferous, are found over extensive areas, passing by insensible gradations into the main leptynite mass.

Intrusive rocks of later age are not common, and ordinary trap-dykes are very rare, only a few small dykes of hornblende-diorite being met with in the hill tracts. In the Aska neighbourhood a fine-grained augite-biotite rock is found interbanded amongst the coarse crystalline rocks. It appears to have been originally intruded into the granitic rocks, and subsequently crushed and foliated with the surrounding rock.

Schist. The bands of schist have been derived from ancient sedimentary rocks, probably ferruginous shaly sands and grits, which have been folded into the crystalline mass. In places it is seen to be only slightly altered, but usually the metamorphosed rock is now a well-defined quartz-garne schist, nearly always containing sillimanite, and occasionally minute grains of graphite.

Mineral limestone. Associated with the schist, and apparently the result of the metamorphism of calcareous beds amongst the ancient sediments, are several interesting bands of crystalline limestone, which are full of accessory minerals. The latter frequently increase to such an extent that the calcite is of rare occurrence amongst the yellow-red garnets, green diopside, felspar, scapolite, quartz, apatite, sphene, and tourmaline. No trace of corundum or its purer forms of ruby or sapphire can be found amongst these minerals.

The junction between the schist and the granitic rocks is seldom seen, but when visible the schist passes over gradually into a more and more crystalline rock, until there is no well-defined boundary between the two series. It is remarkable that no intrusive granite is ever seen amongst the schist.

Economic geology. The Ganjam district is not very promising from an economic point of view, and mica would seem to be the only mineral of possible value.

Gold. Quartz reefs are practically absent throughout the district. Quartzose bands occur amongst the schists, but Mr. Smith was unable to find any trace of gold in any of them. None of the natives of Ganjam carry on gold-washing, and traces of the metal was met with in one stream only, namely, on the Mahendragiri Mountain.

Sapphire. There has for some time been an idea that sapphires were to be found on Mahendragiri. In fact a few transparent and translucent sapphires of some value, said to come from the summit of Mahendragiri, were sent into the office of the Geological Survey for identification. On investigation it appears that a certain 'Kabul merchant' brought down a basketful of earth from a mound at the top of Mahendragiri and that on washing this earth he extracted the sapphires. I have examined the mountain which consists of coarse granitic rocks. There is no

trace of corundum or sapphire in these, and nothing could be found in the remains of the mound which the merchant left. It is probable that the merchant took the stones up with him, or he may possibly have been in the possession of information of a buried treasure.

Mica.

For some years native physicians have bought mica dug from small pits in the Russellkonda neighbourhood. Several veins of course micaceous granite are found in the jungles a few miles to the south-west of that town. Mr. Smith had several pits sunk on these mica outcrops with the result that crystals of somewhat crushed and earthy mica were obtained up to 5 inches in diameter. The coarse micaceous rock, however, seems to be very inconstant and local in its development, and in the pits there was neither enough of the mother-rock, nor were the micacrystals large and pure enough to be of economic importance.

DR. T. L. WALKER. *The Hill Tracts of Vizagapatam.*

The country surveyed comprised that part of the Vizagapatam district contained in the North-East quarter of Atlas sheet No. 93. Four rock groups were recognised, as follows:—

I. *Hypersthene-Garnet Granites and Gneisses* form the whole of the plateau of about 3,000 feet altitude. This rock formation is approximately bounded on the west by a line passing N.N.E. through Jeypore (E. Long. 82°38′, N. Lat. 18°51′). Only about 1,000 square miles of this rock formation were examined, though it is known to extend for long distances north, east, and south.

II. *The Crystalline Schists* occupy the level country to the west of the rocks of group I. To the north of N. Lat. 18°50′ these rocks are generally rather coarse biotite and hornblende gneisses, striking north-west, while to the south they are more varied, hornblende and biotite gneisses and schists, potstone and quartzites. The strike of these southern gneisses is generally north-east. About 1,200 square miles of crystalline schists were surveyed.

III. *Cuddapahs (?).*—Poorly exposed and of a small area these rocks occupy the western and north-western part of the country explored. Lithologically they are made up of purple and grey slates and shales, limestones semi-metamorphosed and lithographic, while near Tetulguma some well-defined conglomerates occur. At various points along the contact of the Cuddapahs (?) and the crystalline schists, hematite quartzites and quartzose rocks, which are possibly crushed conglomerates, occur. As similar rocks in India are at times

auriferous, I crushed and panned several samples, but without finding even the colour of gold.—No fire assays have been made with a view to settling the question as to whether these rocks contain gold or not.

IV. *Diabase.*—In a much altered form occurs near Jeypore and also near Ramagiri, where it forms small hills whose geological relations are not known—it is probably the youngest of the four rock groups and possibly forms dykes.

Economic.—Iron is manufactured in many villages in the area occupied by the crystalline schists. The iron ores are generally poor,—hematite quartz rock, hematite and nodular limonite being the ores commonly used. Potstone is used to manufacture idols, while some of the limestones will be of value for lime and for ornamental purposes. The presence of rocks which may contain gold has already been referred to.

3. Central Provinces.

MR. P. N. BOSE, *Bastar State.*

Part of a gap on the geological map of the Central Provinces comprising the greater part of the Bastar State was surveyed by Mr. Bose. The area is situated between Lat. 19° and 20°, and Long. 80° and 82°; besides this some gaps which this officer left in last season's maps north of Lat. 19° were also furnished. The area reconnoitred would be about 6,600 square miles. The greater portion of the ground—the entire country west of Long. 81°30'—is hilly (the hills occasionally rising to over 3,000 feet above the sea-level), jungle-clad, very sparsely populated, and but little cultivated.

The base rock is gneiss, usually of a granitoid character. Resting upon a denuded surface of it there occur—

I. A transitional series of a pronounced Dharwar facies with hematite qartzite, as its best developed and most prominent member forming straight, deeply notched, sharp-crested, precipitous ridges running along the strike. The rocks cover a very small area and are met with as fragmentary patches having been extensively intruded through by basic igneous rocks since their elevation. The strata are much disturbed; the strike, usually N. S., is, at places, twisted about, and the dip not seldom borders upon the vertical.

II. Rocks lithologically similar to those of the Chhattisgar basin and referable to the lower Vindhyan horizon. They cover almost the

entire country between Lat. 18° 55′ and 19° 30′, and Long. 81° 35′ and 82° 5′. They consist of:—

(*a*) Basal sandstones, often more or less quartzitic and generally coarse, the bottom beds being usually massive and conglomeratic. They as well as the superincumbent shales (*b*) are nearly horizontal or roll about slightly. At Chiterkot (Lat. 19° 12′, Long. 81° 45′) there are exposed some 130 feet of them with interstratified lenticular bands of dark shales.

(*b*) Reddish, dirty grey, and buff shales (with intercalations of sandy beds) often passing into limestones. On the assumption of horizontality, their maximum thickness may be estimated at about 200 feet.

(*c*) Upper sandstones, quartzitic and fine grained. They are as a rule nearly horizontal, but, at one place, were noticed to be highly disturbed and faulted against the gneiss. They overlap the shales (*b*) on to the gneiss.

In the hill country west of Long. 81° 30′ there occur several considerable patches of excessively coarse, massive conglomerates overlaid by quartzitic sandstones and shales—an assemblage of rocks not unlike the lower Vindhyans mentioned above, but differing from these in being intimately intermingled with contemporaneous trappean rocks and in presenting features of greater disturbance.

Besides limestones of good quality in the lower Vindhyans, and rich and extensive deposits of iron-ore, especially in connection with the hematite-quartzite of the transitions, the only mineral of economic importance which was met is mica. Two veins of muscovite were discovered within very coarsely crystalline granitoid rock in the bed of the Baordhiy river south of Jungani (Lat. 19° 45′, Long. 81° 43′). The largest size of plates found measured about 5 inches in length. Being from the surface, however, they are much weathered, cloudy, and cracked. Four miles further south, nests and small veins of muscovite associated with vein quartz abound in coarse, much decomposed granitoid rock.

4. PUNJAB.

DR. F. NOETLING.
Salt Range.

The relations of the upper Palaeozoic to the triassic beds of the Salt Range is of such importance and of such close bearing upon Indian geology generally that it became desirable to revise some of

the work done already by Messrs. Wynne and Waagen in past years and to supplement it by further researches. The late Professor Waagen, who had described the fossils collected in 1872, had come to the conclusion that not only a great gap existed in the sequence between the permian and triassic beds, but that there also existed a great difference between the fauna of the Salt Range and that of the Himalayan trias. According to Professor Waagen this difference is chiefly proved by the absence of the genus *Otoceras*, which he stated positively does not occur in the Salt Range.

Dr. Noetling had frequently expressed his doubt about the correctness of this view. He stated that as far as he could judge from a flying visit paid to one of the triassic outcrops in the Salt Range, there existed a perfect passage between the topmost permian beds and those which were considered to be of triassic age, and consequently the *Octoceras* beds which form in the Himalayas the base of the triassics must, in his opinion, be represented in one way or another. Dr. Noetling felt inclined to consider some unfossiliferous beds at the base of the triassics in the Salt Range as the equivalents of the *Octoceras* beds.

In order to decide this question Dr. Noetling was deputed to the Salt Range, where he examined some of the most important sections near Virgal and Chidru, with the result that it was proved that his supposition of the existence of a gradual passage between the permian and the triassic beds was fully confirmed. Professor Waagen's hypothesis of a break in the sequence fell to the ground as it was plainly and flatly contradicted by actual facts. Shortly afterwards Dr. Noetling reported that he had discovered *Otoceras sp.* in several specimens, but to his greatest surprise not at the base of the Ceratite formation as he expected, but right in the middle of the Ceratite marl. Thus proof was given of the most important fact that not only did the genus *Otoceras* exist in the triassic beds of the Salt Range, but that the whole of the Ceratite marl to which a much higher position was attributed by Professor Waagen must be considered to be the equivalent of the *Otoceras* beds of the Salt Range.[1]

Dr. Noetling examined also the permian system, and he discovered that the main layer of *Xenodiscus carbonarius*, Waagen, was not, as supposed by Professor Waagen, high up in the upper Productus

[1] It is necessary to state that the species of *Otoceras* referred to differs from the Himalayan forms of *Otoceras* in some characteristic details, if indeed it can be referred to this genus. It is certain, however, that it is closely allied to it. (Director.)

limestone, but about 500 feet lower down, near the top of the middle Productus limestone. This is also a very important discovery, inasmuch as it will materially help towards the correlation of certain beds in the Himalayas. Dr. Noetling holds that the trias (ceratite beds) of the Salt Range and the Productus limestone must be considered as subdivisions only of one and the same series, because the gradual passage from the lower beds full of palæozoic brachiopoda to the upper beds in which the ammonites occur makes a stratigraphical subdivision into two great periods an absolute impossibility. The following table shows the sequence of beds according to Dr. Noetling's view, in descending order :—

	German.	Salt Range.		
	Lower Trias.	Baktrian.	Upper ceratite limestone	Zone of *Stephanites superbus*, Waagen.
			Ceratite marl.	Zone of *Flemingites flemingianus*, Waagen.
				Zone of *Koninckites volutus*, Waagen.
				Oboceras beds. Zone of *Prionolobus rotundatus*, Waagen.
Marine Neo-Dyas.		Sindian.	Lower ceratite limestone.	Zone of *Celtites spec.*
	Zechstein.		Upper productus limestone.	Zone of *Euphemus indicus*, Waagen.
				Zone of *Derbyia hemisphaerica*, Waagen.
				Zone of *Productus lineatus*, Waagen.
			Middle productus limestone.	Zone of *Xenodiscus carbonarius*, Waagen.
				Zone of *Lyttonia nobilis*, Waagen.
				Zone of *Fusulina kattaensis*, Waagen.
Marine palæo-Dyas.			Lower productus limestone.	Zone of *Spirifer marcoui*, Waagen.
Glacial palæo-Dyas.	Rothliegendes.	Dravidian.		Lavender Clay unfossiliferous.
			Speckled sandstone.	Speckled sandstone. Bivalve beds. Zone of *Conularia laevigata*, Morris.
				Boulder bed.

5. HIMALAYAS.

KUMAON.
Messrs. LaTouche, Smith, and Walker.

The description of the large Himalayan collections, especially of the upper trias, had made it most desirable that certain localities in the Kumaon Himalayas should be re-visited, and accordingly Mr. LaTouche was deputed to the upper Lissar valley, whilst Mr. Smith was charged with the detailed work in Byans and the Kuti Yangti valley. Dr. Walker was sent to the Chitichun "Klippen" north-west of the Milam passes. The season proved an unusually unfavourable one and severe weather with snowfalls impeded the movement of the three parties considerably. Dr. Walker had to close his field-work very early owing to severe indisposition. However, the results are very commendable and very good collections have been made by these three officers, which will be worked out in due course.

SPITI.
Mr. H. H. Hayden and Dr. A. von Krafft.

Survey work was again taken in hand in Spiti during the hot season of 1899. Mr. Hayden and Dr. von Krafft were posted to that part of the Himalayas and they reached the Spiti valley on the 22nd May 1899. The early part of the season was devoted to joint studies on the lower trias near Muth and a large collection of fossils was made in these beds. Later on the work was divided between these two officers, and each has given a progress report on his share of the survey, which is practically nearly finished, only a few months work remaining to bring the whole up to a certain degree of completeness.

With the exception of some almost inaccessible parts of the snowy range between Spiti and Hundes, the whole of the former district has been mapped and the survey carried through Kanaur and Hundes into Rupshu.

The whole sequence of beds has been examined in as great detail as the time available would permit, and collections have been made from several fossiliferous horizons. The results show that all the systems from upper cambrian to cretaceous are probably represented in Spiti and Bashahr. Considerable attention was paid to the upper trias, several interesting discoveries having been made with reference to that system, which has been found to be more complete than has hitherto been supposed to be the case in the Himalayas. Certain sections which have as yet been only cursorily examined,

promise to yield important results, chiefly with regard to the extent of the permian and carboniferous systems, and when these have been worked out it is hoped that it will be possible to publish a fairly complete memoir on this area.

The following are a few of the more important results obtained by the Spiti party :—

(1) A *trilobite* fauna of upper Cambrian age has been found in the Parahio valley.

(2) An important unconformity has been proved to exist between the Cambrian and Silurian systems.

(3) Upper silurian fossils have been found in Spiti and Bashahr.

(4) A great system of limestones overlain by shales and quartzites—including beds of upper carboniferous and permian age—has been found near Lio in Bashahr. This system is not known to attain such full development in any other part of the Himalayas.

(5) Large collections, including many new forms, have been made from the lower trias beds and have been worked out by Dr. Krafft.

(6) The muschelkalk, from which several forms new to the Himalayas have been obtained, has been found to extend both upwards and downwards further than had hitherto been suspected. The lowest bed in which fossils occur contains a very interesting ammonite fauna.

(7) The upper muschelkalk passes up perfectly gradually into beds of ladinic age, with *Daonella lommeli*, Wiss., and there is no trace in Spiti of a break between the muschelkalk and the upper carnic stage.

(8) No break of any kind has been found in the triassic beds, but there appears to be a perfectly gradual passage from lowest trias to jurassic.

(9) The upper trias beds are of great thickness and contain numerous fossiliferous horizons, many of which can be identified with those found by Mr. Griesbach and Dr. Diener in the Central Himalayas.

In the following table will be found a rough classification of the sedimentary rocks of Spiti and Bashahr :—

Spiti.	Fossil contents.	*Other parts of the Himalayas.*	*Europe.*
Black (Spiti) shales.	Upper jurassic *ammonites.*	Spiti shales.	Upper jurassic.
Grey and black earthy limestones, passing up gradually into the Spiti shales.	*Stephanoceras* cf. *coronato*, Brag. *Spiriferina* cf. *obtusæ*, Opp. (?)*Spirigera nœtlingii*, Bittn.		Dogger. (?) Lias. (?) RHÆTIC.
	Megalodon ladakhensis, Bittn.	Dachstein Kalk in part.	Upper trias.
White and brown quartzites, black shales, and hard grey limestones.	*Aulacothyris joharensis*, Bittn. — *Lima cumanica*, Bittn. *Spiriferina griesbachi*, Bittn.		
Brown-weathering, sandy, and shaly limestone, sandstone and dolomite.	*Spiriferina griesbachi*, Bittn. *Anodontophora griesbachi*, Bittn. *Aulocothyris joharensis*, Bittn. *Distichites*, n. sp. — *Monotis salinaria*, Br. — *Spirigera dieneri*, Bittn.	"Sagenites beds."	
Coral limestone.	*Spiriferina griesbachi*, Bittn. *Rhynchonella bambanagensis*, Bittn.	"Limestone with *Spiriferina griesbachi*."	
Brown-weathering, sandy, and shaly limestones; sandstones and shales, with black splintery limestones.	*Paratibetites tornquisti*, E. v. Mojs. var *Juvavites* aff. *ehrlichi*, v. Hau.	"Halorites beds"	
	(?)*Hauerites n. f. ind.* E. v. Mojs *Paratibetites* aff. *tornquisti* E. v. Mojs.	"Hauerites beds."	
Dolomitic limestone.			

Spiti.	Fossil contents.	*Other parts of the Himalayas.*	*Europe.*
Splintery limestones, grey shaly limestones, and calcareous shales.	*Tropites* cf. *subbullato*, E. v. Mojs. *Tropites* aff. *discobullato*, E. v. Mojs. *Clydonautilus griesbachi*, E. v. Mojs.		
Grey, earthy shales, with shaly limestone partings.	*Spiriferina shalshalensis*, Bittn. *Rhynchonella lankana*, Bittn. ——— *Joannites cymbiformis*, W. *Trachyceras* cf. *aonoides*, E. v. Mojs.	"Daonella beds"	
Hard, dark, splintery limestone with shaly limestone intercalated.	*Halobia* cf. *comatæ*, Bittn. ,, cf. *fascigeræ*, Bittn.		
	Daonalla lommoli, Wiss.		
Black shaly limestones.	*Daonella indica*, Bittn. ,, *lommeli*, Wiss. *Gymnites ecki*, E. v. Mojs. *Trachyceras ladinum*, E. v. Mojs. *Proarcestes bicinctus*, E. v. Mojs. *Ptychites gerardi*, Blanf.		Ladinic stage.
Grey and black concretionary limestones with thin shaly partings.	*Ptychites rugifer*, Opp. *Ceratites thuilleri*, Opp.	Upper. Muschelkalk.	Muschelkalk.
	——— *Spiriferina stracheyei*, Salt. ——— *Ceratites subrobustus*, E. v. Mojs. *Sibirites prahlada*, Dien. *Danubites kansa*, Dien.	Lower. Muschelkalk.	
Nodular limestone.	Very poor in fossils.	Age uncertain.	
Grey, earthy, and concretionary limestones and shales.	*Hedenstrœmia mojsisovicsi*, Dien. *Danubites nivalis*, Dien.	"Subrobustus beds," Diener.	

Spiti.	Fossil contents.	*Other parts of the Himalayas.*	*Europe.*
Black limestones and shales.	*Proptychites ammonoides*, Waag. *Meekoceras*, n. sp. ——— *Ophiceras sakuntala*, Dien.	Otoceras beds. Griesbach.	Lower trias.
Black shales.	*Xenodiscus carbonarius*, Waag. *Cyclolobus oldhami*, Waag. ——— *Brachiopoda* of the "Productus shales."	Productus shales.	CARBONIFEROUS AND PERMIAN.
Calcareous sandstone or sandy limestone, underlain by grits and conglomerates.	*Spirifer musakheylensis*, Dav. *Athyris gerardi*, Dien. *Productus purdoni*, Dav. *Martinia glabra*, Mart.		
Alternating beds of shale and quartzite.	*Bryozoa* (*Fenestella*, etc.) badly-preserved *brachiopoda*.	(?) "Zewán beds" of Kashmir.	
Limestones, slates, and quartzites.	*Phillipsia* cf. *cliffordi*, Woodw. *Rhynchonella* cf. *pleurodon*, Phill. *Derbyia* sp. *Syringothyris* sp.		
Grey limestone, often oolitic and crinoidal.	*Productus* sp. *Athyris* sp. *Syringothyris* cf. *cuspidata*, Mart ,, cf. *distans*, Sow.	Upper carboniferous, *ba*, Mem. G. S. I., Vol XXIII. Griesbach.	
White quartzite.	Apparently unfossiliferous.	Carboniferous.	
Grey siliceous limestone, weathering brownish red.	Fragments of *crinoids* and *brachiopods*.	"Red crinoid limestone." Griesbach	(?) DEVONIAN.
Limestones, marls, and slates.	*Halysites catenularia*, Luck. ——— *Calymene* sp.		Upper. SILURIAN.
Red gritty quartzite, underlain by conglomerates.	Apparently unfossiliferous.		(?) Lower.

Spiti.	Fossil contents.	*Other parts of the Himalayas.*		*Europe.*	
Slates and quartzites, with thin bands of dolomite.	*Ptychoparia* sp. *Olenus* sp. and other upper Cambrian trilobites.			Upper.	CAMBRIAN.
Red quartz-schists, slates, and carbonaceous shales.		Upper.	Haimanta.		
Quartzites and slates.		Middle.			

6.—SIND.

DR. FRITZ NOETLING.
MR. E. VREDENBURG.

As a considerable difference of opinion existed with regard to the development of the tertiaries in Baluchistan and Sind, Dr. Noetling was deputed during the second-half of the season to Sind, where he was later on joined by Mr. Vredenburg.

Dr. Noetling thoroughly examined the northern part of the Laki range, while Mr. Vredenburg studied the country in the neighbourhood of Ranikot. Later on the party examined the country between Jhirrak and Meting. Though only a comparatively short time could be devoted to these researches the results obtained are very important, and the view which Dr. Noetling held with regard to the middle eocene of Baluchistan—namely, as being an equivalent of the Ranikot group—has been fully proved to be correct. Dr. Noetling and Mr. Vredenburg brought together a splendid collection of fossils, and though a considerable time will elapse before these will be described, the systematic researches of these officers have shed quite a new light on the stratigraphy of Sind. As the eocene was chiefly examined, these new observations concern of course that sub-division of the tertiary system only, and according to Dr. Noetling the sequence of the eocene is as follows in descending order:—

NARI-GROUP . . { 17 Zone of *Cerithium*, spec. nov.
16 Zone of *Eupatagus rostatus*, d'Arch.
15 Zone of *Echinolampas discoideus*, Dup. }

RANIKOT-GROUP	14 Khirthar limestone. 13 Zone of *Anomia*, spec. nov. 12 Zone of *Cardita*, spec. nov. 11 Zone of *Pugnellus*, spec. nov. 10 Zone of *Nummulites granulosus*.
LOWER EOCENE	9 *Alveolina* limestone. 8 Zone of *Macropneustes speciosus*, Dup.
UPPER CRETACEOUS	7 Zone of Gen. nov. spec nov. (*Rostellaria*, spec. Bland.) 6 Unfossiliferous sandstone. 5 Zone of *Ostrea lingua* (?) 4 Basalt. 3 Zone of *Turritella*, spec. nov. 2 Zone of *Cardita beaumonti*. 1 Nodular limestone.

The above sequence differs considerably from that first established by Dr. Blanford. In fact it appears that Dr. Blanford mapped as Khirthar limestone (upper eocene) a considerable part of the limestone which in the above sequence appears as No. 9 below the Ranikot-group.

If we consider the limestone No. 9, which Dr. Noetling calls alveolina limestone, to be an equivalent of my alveolina limestone of Baluchistan, the sub-division of the eocene both in Sind and Baluchistan is precisely alike, namely :—

SIND.	BALUCHISTAN.
Khirthar limestone.	Upper eocene limestone (Spintangi, Oldham).
Ranikot-group.	Middle eocene shales.
Alveolina limestone.	Lower eocene limestone (alveolina limestone).

7.— BALUCHISTAN.

MR. E. VREDENBURG.

After returning from the Seistan Mission, which Mr. Vredenburg accompanied during the season 1898 to 1899 (see last year's General Report, pages 63, etc.), this officer was deputed during the hot months of last year to the Kojak range and the Toba plateau in Baluchistan to study the peculiar Kojak formation in greater detail and to compare it with the south-western extension of it, which he had already met with during his Seistan tour. The full report on this survey, it is hoped, will appear when some gaps in the geological maps east of this area are filled in and when it will be possible to bring out a volume descriptive of the

geology of Baluchistan and compiled by the several observers who have worked out the details of it. Regarding the Kojak range Mr. Vredenburg writes in his official diary:—" * * * I had stated that the broad range east of Nushki, consisting of many parallel ridges, which is the southern continuation of the Kojak or Khwaja Amran, consists of two different systems of strata: the western margin of highly cleaved slates with narrow beds of sandstone, and with much vein-quartz, I took at first to be some palæozoic rock; afterwards absolutely similar rocks were found to be highly metamorphosed eocene. All the eastern portion of the range consists of sandstones and shales in which I found no fossils; they are much folded, but neither cleaved nor metamorphosed like the rocks along the western margin and contain no quartz-veins. I met with similar rocks, always unfossiliferous in several places in the desert, and have several times altered by opinion as to their age, owing to the disconnected and unmethodical manner in which this season's work was unavoidably performed. In the present instance a careful examination of the section from Nushki to Kishingi showed that the one type of rock passes quite gradually into the other; the slates along the western margin are merely metamorphosed representations of the shales which constitute the eastern ridges. A few bands of limestone with crushed fossils occur indifferently in the slates and in the unaltered shales. On closer inspection it was found that the calcite veins common in the unmetamorphosed shales exist in the slates as well; the quartz-veins are restricted to the slates and are a result of metamorphism. In some portions of the Kharan hills, where the rocks were locally less disturbed than usual, they assumed the same facies as these shales and sandstones, and in this case a few fossiliferous beds contained *nummulites.* It may, therefore, be regarded as established that these rocks are eocene; they owe their peculiar facies to a greater development of the arenaceous element or a dwindling of the limestone; they would correspond probably to the Ghazij division[1] of Mr. Oldham. Such a conclusion simplifies the interpretation of all the regions where these rocks have been observed. The same rocks are the only ones I have met with, so far, in the Pishin district. I have examined nearly all the valleys that descend from the Toba plateau to the north-west, north, and north-east of Pishin. The rocks are quite similar to those met with

[1] Middle eocene, Griesbach.

between Nushki and Kardagap; the strata are generally somewhat gently undulating, but, just as in the Nushki region, the folds become sharper and slaty cleavage sets in as the Kojak range (or its northern continuation) is approached. * * At the time of my first visit the range east of Kardagap (southern continuation of the Ghaziabad range) was crossed along the 'Kurd Barak' pass, where the rocks were almost entirely concealed. On the present occasion I crossed it further south and was able to observe that it consists almost entirely of massive nummulitic limestone with some very subordinate shale bands. It is flanked by siwaliks on either side."

Part III.

Progress Reports of Officers of the Geological Survey of India for the year 1899-1900.

Note *on the* Auriferous reefs of South and South-East Wainád, *by* H. H. HAYDEN, B.A., B.E., *Officiating Deputy Superintendent, Geological Survey of India.*

Prospects of gold mining in Wainád.

During the past few months an examination, on a small scale, has been made of the more important reefs in South and South-East Wainád, the general results of which tend to show that the majority of the reefs are probably too poor in gold to offer any prospects of remunerative working; yet it is possible that one or two may prove sufficiently rich to justify mining operations, provided these are carried on judiciously and under strictly expert supervision. This opinion, however, is given with considerable diffidence, for the scale on which the examination has been carried out was so small, as to render it a matter of extreme difficulty to arrive at any reliable conclusions as to the average value of a given reef. This difficulty is intensified by the fact that the gold appears to be most capriciously distributed. Till, therefore, trials on a considerably larger scale have been made, any recommendation as to the advisability or otherwise of the resumption of mining operations would seem hardly justifiable. Many of the reefs, however, have yielded consistently poor results, and of these it may be safely assumed that they are not likely to be worth working: but a few have given results ranging from over an ounce to a few grains of gold per ton of ore, and these results should warrant the undertaking of more extensive investigations.

Reefs.

Auriferous reefs occur both in South and South-East Wainád.[1] In the latter area, however, they are by far the more numerous, and are to be found chiefly in the neighbourhood of Dévála and Pandalur. Most of these reefs

[1] King, Rec. G. S. I., Vol. VIII, 2 (1875).
,, ,, ,, Vol. XI, 3 (1878).
Brough Smyth: "The Gold Mines of the South-East Wainád and Carcoor Ghát." (1880.)

have been re-examined, but in the present short note it will be sufficient to mention only those which have yielded an appreciable amount of gold.

Skull reef.

The most important of those near Dévála are found on the edge of the ghât between Sulimalai (Hill) and Nadugáni, and include those formerly known as the Skull, Bear, Cavern, Kurambar, and Hamlin's reefs. Of these the Skull reef is the only one which has yielded more than a small percentage of gold. It was worked to some extent by the Alpha Gold Mining Company, and numerous drives and adits are still to be seen, though in most cases, owing to the heavy rainfall on the edge of the ghât, they are more or less blocked up by the falling in of the roof.

The reef is composed of white quartz containing highly pyritous bands of varying thickness, and it is in these bands that most of the gold is found, the white non-ferruginous quartz being almost barren. The casing, which is formed of a more or less brecciated mass of quartz, talcose, and schist, and decomposed iron ores (now chiefly limonite or hæmatite), is also frequently rich, but its thickness is usually only a few inches.

The following list contains the results of a few tests made on the Skull reef:—

Number.	Locality.	Amount crushed.	Amount of gold to ton of ore.	Portion of reef represented.
			oz. dwt. gr.	
1	Kurambar tunnel S. E. end.	600lbs.	0 1 13	Whole reef.
2	Open quarry west of Alpha Company's bungalow.	93lbs.	0 0 18·5	Ditto.
3	No. 9 adit . .	7lbs.*	0 13 1	Ferruginous portion of reef, 2 feet thick.
4	Ditto . .	6lbs.*	0 11 16	Ditto.
5	Ditto . .	7lbs.*	0 3 8	Whole reef.
6	No. 7 adit . .	7lbs.*	Traces.	Ditto.
7	Ditto . .	6lbs.*	1 7 6	Upper part of reef (one feet six inches thick) and casing.
8	Ditto . .	7lbs.*	1 0 0	
9	Ditto . .	5lbs.*	4·16 dwts.	Ditto.
10	Ditto . .	7lbs.*	8·93 ,,	Ditto.

* Taken by sampling from a mass of about 200 lbs.

The results obtained from the Bear, Kurambar, and Hamlin's reefs were all small, the highest being from the Kurambar reef, *viz.*, 4·66 dwts. to the ton. None of these reefs have been exploited to any extent by the Gold Mining Companies, but the Bear reef was worked by the old native miners, who furrowed out small tortuous passages along the reef in order, apparently, to get at the casing. A small adit of about 30 feet in length represents the only mining done by Europeans. In this adit is a small leader—six inches thick—of highly pyritous ore, which yielded gold at the rate of 10 dwts. to the ton.

Bear reef.

Hamlin's reef was formerly mined to some extent, but almost all the old workings have fallen in. One adit is still open, but the reef is not seen in it, a leader only having been opened up. This leader is ten inches in thickness and contains visible gold. Seven lbs. of quartz from it was taken out of a mass of about 150lbs. and yielded gold at the rate of two ounces to the ton: the sample treated showed no visible gold.

Hamlin's reef.

The Kurambar reef has also been opened up by a small adit. Two samples of quartz taken from this adit gave—

Kurambar reef.

1. Trace of gold: from 7lbs. of ore.
2. 4·66 dwts. to the ton.

The results obtained from most of the other reefs in the neighbourhood of Dévála were poor, usually about 1 dwt. or less to the ton.

Of the reefs in the neighbourhood of Pandalur, those on the Richmond and Phœnix Estates have been mined; the former, which is seen near the Richmond tea-factory, has been opened up by an adit about 300 feet long, from which small drives have been run along the reef, which is here about four feet thick and carries a band of highly pyritous ore: the thickness of this band is about one foot. Two samples treated gave respectively 1 oz. 7 dwts. 4·8 grs., and 5¼ dwts. of gold to the ton of ore.

Richmond.

The largest mine in South-East Wainád is that on the Phœnix Estate. The reef has been worked on three different levels, and the mine while under expert management is said to have paid expenses, work having eventually been stopped by the orders of the Government of India, in consequence of the frequency of accidents which resulted in the death

Phœnix.

of several native miners. The ore, however, appears to be of quite a low grade, yielding only about 2 dwts. of gold to the ton. The gold is very finely divided, but appears to be distributed fairly regularly throughout the greater part of the reef, though richer bands with much pyrites occur in places. The reef, which has an average thickness of about four feet, has been proved over a considerable area.

Geology of South-East Wainád.

The rocks of South and South-East Wainád fall roughly into seven classes, *viz.*—

1. The charnockite series. (Acid, intermediate and basic varieties.)
2. Hornblendic rocks, associated with the charnockites.
3. Biotite gneiss.
4. Biotite granite.
5. Pegmatite veins.
6. Younger basic dykes.
7. Quartz reefs.

Charnockite.

The *charnockites* form the mass of the Nilgiris bordering on Wainád, and are found at various points intrusive in the biotite gneiss, forming in fact most of the more striking hill masses in South and South-East Wainád. On their borders, and apparently connected with them, occurs a series of *hornblendic rocks*, often resembling old basic dykes, now represented by pure hornblende rocks or epidiorites; these too contribute some important features to the landscape.

Hornblendic rock.

Biotite gneiss.

The *biotite gneiss* is everywhere soft and highly decomposed. In South-East Wainád it is usually more or less hornblendic, probably owing to the numerous intrusions of charnockite. It is, as a rule, the country rock in which the quartz reefs occur.

Biotite granite.

Biotite granite, strongly resembling the "dome gneiss" of Hazáribagh, occurs at Sultan's Battery and Kalpata Hill, and is probably connected with the numerous veins of pegmatite found throughout Wainád.

Pegmatite.

The *pegmatite* veins which appear to run more or less at right angles to the quartz reefs, *i.e.*, practically parallel to the strike of foliations of the country rock, are composed of great masses of quartz and felspar with fairly large crystals of mica: the only other mineral hitherto indentified in them being garnet, which is not common. The mica, which is "ruby" mica, is of excellent

Mica.

quality, occurs in considerable masses, and crystals of over 2 feet × 2 feet have been found. Mining is being begun on a small scale, but at the time of my visit amounted to little more than a few scratchings of the surface: but there is good reason to hope that before long mica mining will prove an important and prosperous industry in Wainád.

Dykes.

The *younger basic dykes* have been found only in two localities in South Wainád, and consist of fairly fresh rocks approaching dolerite in composition.

"Country" rock.

In most cases the country rock in which the quartz reefs occur is biotite or hornblendic gneiss; it is always decomposed to a depth of a hundred feet or more, and is so soft that it can be readily dug out with a pick, and blasting is almost unnecessary. Tunnelling is therefore easy and rapid, but this advantage is considerably discounted by the fact that the softness of the rock necessarily involves very extensive timbering.

Facilities for mining.

Most of the reefs are found cropping out on the edges of the ghâts and can therefore be worked down to a depth of several hundred feet by means of adits run in from the hill sides.

Timber.

Timber is no longer available in the immediate neighbourhood of the veins, but could be obtained in large quantities from the forests at the foot of the ghâts.

Water.

With the exception of that on Richmond Estate, all the reefs mentioned above are situated near perennial streams, and water-power sufficient to run a considerable amount of machinery would be obtainable; this would of course involve the construction of dams.

Labour.

Labour, at the rate of four annas per diem, is said to be available in large quantities in the neighbouring taluk (Ernád taluk of Malabar).

Roads.

Much of the road from the nearest port and Railway station, Calicut, is in a hopeless state of disrepair and is said to be impassable for wheeled transport during the monsoon. The worst portions, however, are being taken over by the Government and will probably in the course of a year or so be restored to their former excellent condition.

So much for the *natural* conditions, which bear on the question of the success or otherwise of mining operations in Wainád. One point, however, still remains to be considered, *viz.*, the question of land tenure, and of such vital importance is this, that it has seemed advisable, even in the present short note, to enter into the matter at some length.

Land tenure.

In South-East Wainád, owners of all lands may be divided roughly into two classes, *viz.*—

A. The Government of India.

B. Owners other than the Government of India. An owner of this latter class is termed a "private jaumi."

In the first case the Government of India is the absolute owner. In the second case, the lands are held by the owner or *jaumi* subject to a tax or rent known as *assessment.*

(1) Lands included under class A, *i.e.*, lands of which the Government of India is the jaumi, when taken on lease, are subject to the following charges :—

(*a*) Assessment, paid on the whole or only a portion of the land, at rates varying from six pies to two rupees per acre according to the quality of the land.

(*b*) *Jauma-bogum* or rent, usually at the rate of eight annas per acre.

The payment of the above charge is made of course to the Government of India.

(2) Lands held on lease from a private jaumi (class B) are also subject to similar charges, *viz.*—

(*a*) *Assessment,* at the same rates as above, paid to the Government of India, by the *occupier,* whether he be the owner (jaumi) or a tenant ("patadar").

(*b*) *Jauma-bogum* or rent, paid by the tenant or lessee to the private jaumi *at such rates as may be fixed by private arrangement between the parties concerned.*

All lands held for purposes of gold mining, whether held directly under the Government of India, or on lease from a private jaumi, are subject to a *Government* royalty of 7½ per cent. of each year's net profits.

In the case therefore of lands of which the Government of India is the jaumi, the *maximum* charges to which they will be subject may be estimated at about R 2-8 per acre, *plus* a royalty of 7½ per cent. on the net profits of mining operations, while, on the other hand, lands held under a private jaumi will still be subject to assessment (at a *maximum* of R2 per acre) and a royalty of 7½ per cent. on net profits of mining, and, in *addition*, rents or other charges (such as royalties, etc.,) at a rate to be arranged between the private jaumi

and the intending lessee, and as most of the auriferous lands of South-East Wainád belong to large native landed proprietors, who naturally wish to make the terms as profitable to themselves as possible, there is some danger that they may refuse to grant leases except on prohibitive terms, thereby putting a veto on all mining till they can be induced to accept more reasonable offers. This danger indeed seems imminent at the present time and if allowed to continue will seriously affect the new and promising mica-mining industry.

Preliminary Report *on the* Auriferous tract *in the* Wuntho District *in* Burma, *by* G. A. STONIER, A.R.S.M., F.G.S., *Mining Specialist, Geological Survey of India.*

During the field-season of 1899 to 1900 I was engaged in investigating the conditions under which minerals (particularly gold) occur in the district bounded by Banmauk on the north, Kawlin on the south, Seu on the east and Pinlebu on the west. I have done as much original prospecting as was possible during the time at my disposal, but the work was seriously impeded by the want of skilled labour with which to carry out ordinary methods of prospecting such as are adopted in America and Australia.

During the month of February I was employed in detailed prospecting work, a close study of the Choukpazat lode (underground and on the surface), and the survey of several traverses which were necessary on account of the incomplete character of the plans supplied to me.

Choukpazat.

The Choukpazat reef was discovered by Burmans and the outcrop was worked by them to a depth of 8 or 10 feet. Mr. C. M. P. Wright, who was prospecting in the neighbourhood in 1894, came to these old excavations and after

a series of tests, he discovered the shoot of gold and commenced to sink upon the reef. To illustrate the difficulties connected with the preliminary proceedings, it may be mentioned that, at one time, the strike of the vein was believed to be north and south, and it was only by a considerable amount of work that the direction was found to be E. 30° N., and the underlie to be S. 30° E. at 62°. The vein has been proved to a depth of 420 feet, though all the slopes are above the 310 feet level. The length of the vein is 240 feet and the richest part of the deposit has been found midway between the north-eastern and south-western boundaries. The thickness varies from two inches to ten feet and averages about three feet six inches. The veinstone contains 14 dwts. of gold to the ton of stone and consists chiefly of a compact quartz, generally white in color, but in places banded with black streaks which are roughly parallel with the walls of the vein and show very clearly by candle-light in the mine. The quartz varies considerably in character and below the 310 feet level is associated with calcite: in places it is devoid of an accompanying mineral, but in other parts of the vein there is so much galena, copper pyrites and iron pyrites present that the ore has the appearance of a complex copper-ore.

The free gold is fine, irregular in occurrence and is most abundant where altaite (telluride of lead, tin-white in color) is present: it is frequently associated with copper pyrites and is visible at the 310 feet level. Unless the character of the stone be known, a heap of milling ore may be examined without a single "specimen" being discovered: under the circumstances it is needless to add that miners do not steal specimens.

The footwall and hanging-wall are sometimes well defined and the latter is polished and occasionally striated. "Horses" (*i e.*, included country) are of common occurrence and have been found to carry payable gold. "Breaks" are met with in the footwall and less frequently in the hanging-wall.

The vein is cut off on the south-western end by intrusive felsite(?), a description of which must await microscopic examination. The vein thins as it approaches this rock and passes into a small mullocky vein at the junction of the intrusive and intruded rocks. At the north-eastern end the lodestuff appears to be cut off at the outcrop by a fault, but in the Main Adit (94 feet level) there is no sign of a fault, and the vein gradually thins until it cannot be traced even as a division-plane traversing the country. Below the Main Adit

the levels have not been extended in a north-easterly direction from the main shaft, which latter is wholly in ore. It is of considerable importance that the mine should be proved, not only in depth, but also in the horizontal direction indicated.

Attempts to trace the extension of the view, beyond the auriferous shoots, have failed both in a north-easterly and south-westerly direction.

Specimens sent by Mr. Wright from the hanging-wall at the 310 feet level have been examined by Messrs. Middlemiss and Holland, both of whom report it to be a "pyroxene rock." I think that both the hanging-wall and footwall belong to the series in which are the tuffs, a series largely developed in the district. The rocks have the general appearance of sediments, although it was impossible to obtain evidence of their sedimentary origin—the sections are poor. In some respects the rocks resemble a thick series of tuffs, breccias, etc., of devonian age which I discovered at Bingera (New South Wales), and in the absence of palæontological evidence I should consider the Choukpazat rocks to be as old as the Australian beds referred to.

Within 75 yards of the outcrop of the Choukpazat vein, intrusive diorite has been found: a specimen, selected by me, has been examined microscopically by Mr. T. H. Holland. This rock can be traced in a northerly direction along the Choukpazat Stream as it is found at intervals for a distance of one mile.

A mass of diorite occurs at Shintha, four miles north of Choukpazat village, and appears to be on the same line of disturbance. Taking into consideration the wavy line of junction, the occasional (perhaps even frequent) alteration of the tuffs, at the junction, and the thin tongues of diorite penetrating the tuffs, there is no room for doubt that the diorite is of later age and intrusive into the tuffs.

The evidence for the relation of the felsite to the tuffs is not as satisfactory but is, I think, sufficient to establish the intrusive character of the felsite. At about one mile south of Choukpazat village a good section is seen: porcellanites rest vertically on felsite, which latter is indistinctly schistose in places.

The mode of occurrence of the quartz and its association with calcite show that the quartz, occurring in the vein, is not interbedded but is younger than the enclosing rocks and has been deposited from solution. The question will be more fully dealt with in a subsequent report.

Half a mile in a northerly direction, a quartz reef (parallel to, and in the same country as the Choukpazat vein) has been discovered but has not been prospected.

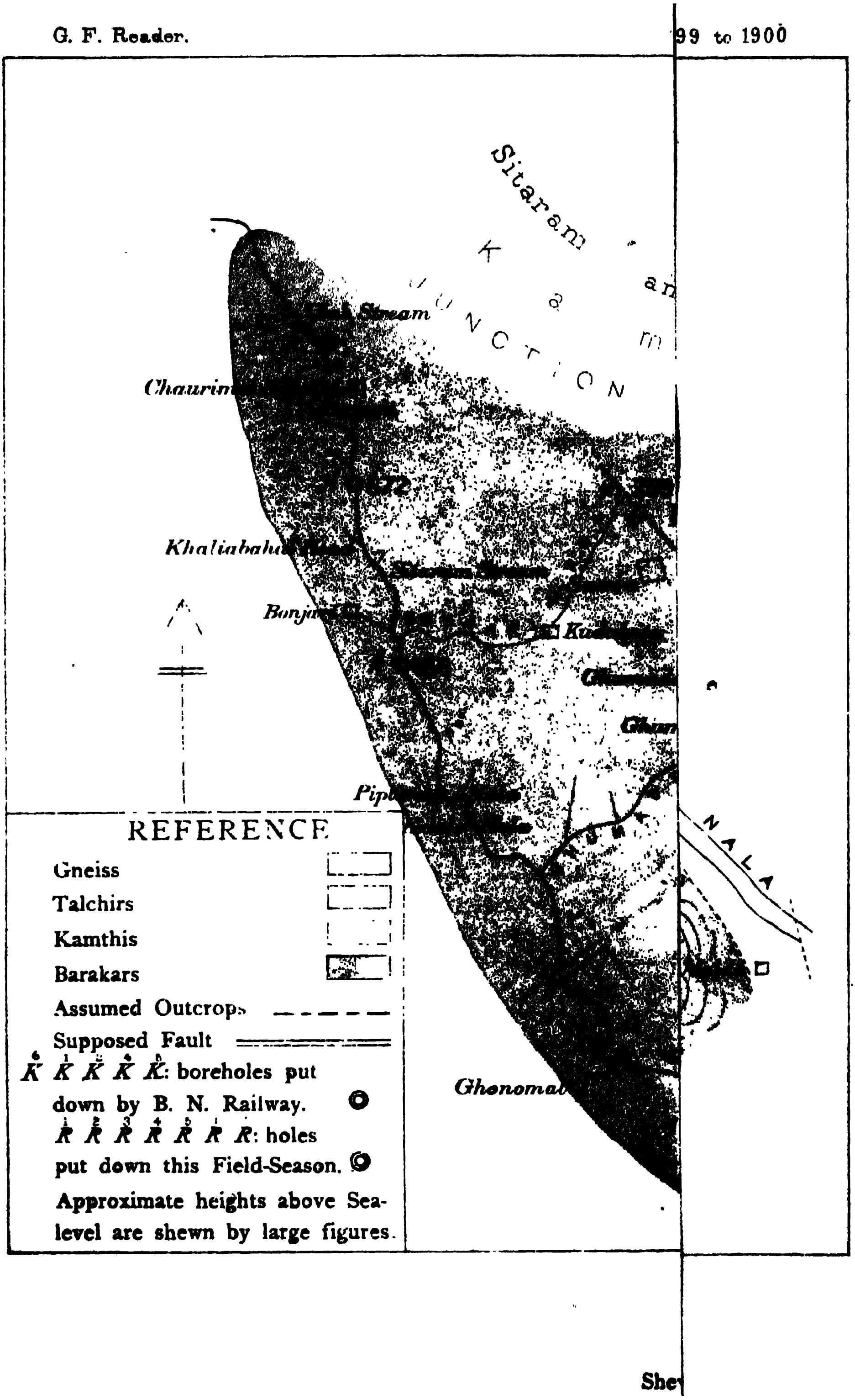
Nine hundred yards to the north-north-east two quartz veins have been found. One, known as the Peregrine, has been cut by an adit 136 feet long and a level is being driven N. 10° W. in a direction along the vein which varies from 12 to 16 inches in thickness: a quantity of ore has been raised and awaits treatment. Seventy yards west-north-west of the Peregrine adit, a vein known as the Masheeboo has been cut in a level driven 24 feet S. 51° E. and N. 51° W. from an adit ninety-five feet long. The reef is seen only in the western end of the level and varies from an inch to a foot in thickness. A parcel of ore is being raised.

The mill is situated on the Nevalabo Choung, one mile north of Choukpazat village, and consists of a ten head stamps battery (750lbs. stamps, 7 inch drop, 92 blows per minute, ·02 inch screens) with ordinary amalgamated copper plates and two small shaking tables: nine dwts. of gold per ton are obtained by amalgamation. Concentrates are collected on two Frue Vanners and are being stored with a view to the erection of a suitable plant for their treatment. The tailings contain 3 dwts. of gold per ton: a small cyanide plant is being erected to deal with them. The following table illustrates the method:—

ORE.

Free gold.	Concentrates.	Tailings.
Amalgamated in the boxes of the battery and on the copper plates.	Sorted and awaiting treatment.	To be treated by a small cyanide plant in course of erection.

There is no doubt that free gold will be found in the auriferous shoots at greater depths than 420 feet to which the Choukpazat vein has been proved. This feature is of importance because it means that a fair percentage of the gold in most of the workable lodes can be extracted by the aid of simple machinery. Only one complete plant is necessary for the district, and the concentrates from the smaller mines could be sold on assay value to the owners of the larger plant. There has not been as favorable an opportunity as the present for the development of small mines: a comparatively


Sitaram
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Gneiss
Talchirs
Kamthis
Barakars
Assumed Outcrops
Supposed Fault
K K K K K: boreholes put down by B. N. Railway.
R R R R R R R: holes put down this Field-Season.
Approximate heights above Sea-level are shewn by large figures.
She

small addition would make the Choukpazat plant suitable for the purpose indicated.

Legyin.

Eleven miles north of Choukpazat an area is being prospected by Mr. N. Lazarus. Several quartz veins have been discovered and a level thirty-four feet in length has been driven along a reef bearing north-west and heading 10 degrees to the south-west. The reef varies from 15 inches to 2 feet in width, is well defined and worthy of exploitation. The other veins, referred to, have not been prospected.

Conclusions.

The two properties described in this report are the only places where work is in progress, and as will be seen from my remarks only one payable vein has been found up to date.[1]

Preliminary Report *on the* Rampur Coal-field, *by* G. F. READER, F.G.S., *Mining Specialist, Geological Survey of India.*

Area examined.

The part of the Rampur coal-field which has been examined this field-season (December 10th 1899 to February 17th 1900) is shown on the map (dated 1875) as lying between parallels 21° 45′ and 21° 51′ and meridians 83° 50′ and 84° 1′.

Previous Writers.

The previous writers on this coal-field are :—

Dr. V. Ball, Rec., Geol. Surv. of India, Vol. viii, pt. 4; Dr. W. King, Rec., Geol. Surv. of India, Vol. xvii, pt. 3, Vol. xviii, pt. 4, Vol. xix, pt. 4, Vol. xx, pt. 4.

[1] Since the above was written, Mr. Stonier has discovered a quartz reef with payable gold about 14 miles north of Baumank. The reef consists of quartz, is nine inches in thickness and where tested it contains 9 dwts. of gold per ton of ore. There is also about 2 per cent. of copper in the form of chalcopyrites.

Previous History.

One thick band of carbonaceous shale with coal-bands interbedded and several minor seams were disclosed in the Lillari stream. As the result of surface exploration in this area, and evidence deduced from bore-holes put down in the Lillari valley under his directions in 1884 to 1886, Dr. King says, "I am reluctantly compelled to recommend its abandonment." In a later Report (Vol. XX) Dr. King, not considering the evidence of bore-hole samples sufficiently trustworthy, advised sinking a pit near Chowdibahal. The general results of these investigations were, however, considered unfavourable, and no further action was taken in prospecting for coal until the discovery of a seam of coal under the site of the Eeb bridge on the Bengal-Nagpur Railway. On this discovery a grant was made by Government to the Bengal-Nagpur Railway Company to explore the coal area round Telanpali. For this purpose five bore-holes and one shaft were put down. I have marked four bore-holes and the shaft on the annexed sketch-plan of the area. One bore-hole I have not been able to locate on account of the inaccuracy of the map. The general result of this exploration (by the Bengal-Nagpur Railway Company) was not encouraging, but on the report being submitted to Mr. Griesbach, he advised the deepening of bore-hole No. 4 (K4 of map) until undoubted Talchir rocks were struck "not being satisfied that the lower measures of the Barakars (which usually contain the best coal seams)" had been sufficiently proved. In pursuance of this opinion Government sanctioned the work of carrying the boring to a depth of 400 feet and subsequently to a depth of 600 feet. At a depth of 347 feet a seam of coal 7′ 9″ thick, with a 6″ band of stony coal in the middle, was struck, then for a hundred feet a remarkable succession of alternating bands of thin coals and shales were encountered, and the remaining 37 feet passed through "fine-sandstone"—the hole being stopped at a depth of 485 feet in this sandstone before reaching the Talchirs.

This boring result was deemed by Mr. Griesbach sufficiently encouraging to advise going on with the work for another 100 feet or so, unless the crystalline rocks were struck at a lesser depth. The boring contractors pointed out that the cost of drilling to this depth would be very great, and Mr. Smith was deputed to visit the spot to ascertain whether it could be regarded as reasonably certain that two borings to a depth of 500 feet would give the same information as one to a depth of 1,000 feet and if strong evidence existed in favour of this conclusion, to mark the exact position at which the

second bore-hole should be drilled with reference to the one under discussion.

The examination did not answer this question and it was considered a better plan to select a site near Dhoramuda, practically at the top of the Barakars, and bore through the whole thickness to the Talchirs or Crystallines as the case might be. Had the coal-field been previously laid down on an accurate map I venture to think that such site would not have been chosen, since it would have been evident that at that point the thickness of measures would be nearly if not quite double what they were anticipated to be. However a bore-hole was put down here to a depth of 828½ feet only which passed through several shaly coal seams (not one workable) finally stopping in the zone of Barakar Rocks exposed in the Lillari nala near Piplimal, several hundred feet above the top (geologically speaking) of the Kodopali boring (No. 4) and only proved the ground already proved by Dr. King in his Nos. 1, 2a, 3, 4, 5 and 6 bore-holes. It will therefore be seen that the lower measures of the Barakars have not been proved as was intended.

Object of present survey.

The object of this survey was to reconcile as far as possible previous apparently conflicting data and ascertain the probability of existence of a workable seam or seams of coal. My first endeavour was to establish a working vertical section from exposures in the Lillari valley for correlation with parallel sections in the Eeb river and Bichwa nala, and to enable me to fix the horizons of the seams discovered in the various bore-holes in the course of this preliminary work, I was forced to the conclusion that the topographical sheet was not sufficiently accurate for recording geological observations. I was therefore compelled to re-survey the whole area topographically and as a consequence geologically too.

Inaccurate map.

Scope of report.

For the purpose of this Progress Report I will confine myself to the economic resources of the field, leaving the data upon which the geological map is based for my final report.

Estimate of thickness.

Work was commenced in the Lillari nala and as complete a working section as possible was established from surface observations, from the Talchirs up to the Kamthis. On the evidence of this section alone I should place the thickness of the Barakars at about two thousand feet. There is

a great difference between this figure and those of previous writers. The inaccurate map previously used will account for some of it, but even then I fail to understand why so low a figure was assumed. I have not, however, been able as yet to make use of the evidence deducible from Dr. King's bore-holes in the Lillari valley, since no information is to hand of their exact positions.

Seams in the Lillari nala.

Four carbonaceous bands were met with in the Lillari nala (see plan R^1, R^2, R^3, R^4) near Durlipali, Bonjari, Khaliabahal, and Dhoramuda Ghât. Small pits were sunk into these outcrops and the following sections obtained:—

DURLIPALI:—*Base of seam R^1.*

	Ft.	in
Two inches of coal with shale	0	11
Argillaceous shale	3	0
Carbonaceous shale	2	0
Coal	0	2
Carbonaceous shale		
Base		

Bonjari, R^2.

	Ft.	in.
Argillaceous shale	2	0
Clay ironstone	0	3
Carbonaceous shale	2	3
Coal	0	9
Carbonaceous shale	1	0
Coal	0	5
Carbonaceous shale	0	9
Coal	0	5
Carbonaceous shale	1	4
Coal	0	2
Carbonaceous shale	0	7
Coarse sandstone		
Base		

Khaliabahal, R^3.

Top	Ft.	in.
Clay	2	0
Carbonaceous shale	0	4
Coal	0	4
Carbonaceous shale	0	4
Shale with coal-pipes	2	4
Carbonaceous shale	1	0
Coal	0	6
Carbonaceous shale	0	5
Coal	0	2
Carbonaceous shale	0	10
Sandstone		
Base		

Dhoramuda Ghât, R^4.

	Ft.	in.
Carbonaceous micaceous shale	2	6
Sandstone		
Base		

It will be seen that none of these bands contains coal of workable thickness. Nevertheless samples of coal were extracted from each band and tested. The result was indifferent in each case, the average ash exceeding 35 per cent.

On the result of these holes, however, I do not feel justified in condemning these seams. It is highly probable that some change will be found to take place in their quality to the east and west and to the dip of the point proved.

My next intention was therefore to get a correlative section in the Bichwa nala—marked on the Topographical Survey map as flowing more or less parallel to the Lillari nala, and about a mile or a mile and a half to the west of it—to see how these seams varied in quality and thickness, etc., to the west and to get some idea as to the nature of the ground intervening. I was very much disappointed on finding that there is no Bichwa nala, nor any other stream flowing towards the south; indeed the water from the hills ranging from Burtab to Sahujbuhal flows to the east into the Lillari.

New plan and deductions.

By this time, however, my new plan was beginning to show the topographical map more incorrect than I had thought, and it became evident that opinions based on work done on this map must require reconsideration; in fact, the correlation of the Eeb Bridge and Durlipali seams did not appear plausible.

Modlia nala.

I then turned my attention to the neighbourhood of the Eeb river and the nalas flowing into it on the right bank and the Bonum nala on the left bank. Commencing near the source of the Modlia nala diligent search was made for some shale or coal seams to correlate with the Bongasi and Khaliabahal beds. In its upper reaches the Modlia nala gives many rock sections, and I was therefore at a loss to understand why some carbonaceous shale or coal beds were not met with. The discovery of what appear to be Talchir shales, however, further down the stream proving, in such a case, a down throw fault to the east, explained this and at the same time showed that representatives of these carbonaceous shale beds must be sought for much further to the west and north than this report is dealing with.

Eeb river.

Attention was then directed to the Eeb river, and here I was successful in unearthing, as anticipated, coal outcrops (correlating with the Eeb Bridge seam) at two points—R^7, R^6—of great moment in that they will materially aid in solving the field—approximately $1\frac{3}{4}$ and 3 miles down the river from the bridge.

Holes were put down at these points and also at Lumchibahal Bridge (R [5]), where curiously enough, the same seam, I believe, was proved on the same day—I thought then for the first time, but subsequently found it was not so.

The sections, as deep as the pits could be taken with the labour at hand, are—

	Rampur section R6.	Ram Adin section R7.	Lumchibahal R5.
	Ft. in.	Ft. in.	Ft. in.
Conglomerate	...	...	...
Grey shale	...	...	7 0
Black earth	4 0	6 0	5 6
Coal	4 9	2 2	1 6
Batt	0 8	1 6	↓
Coal	3 1	3 3	↓
Batt	1 9	↓	↓
Coal anticipated	↓	↓	↓

Laboratory and also large scale tests were made with the following average result. (Moisture 9%, vol. m. 17%, ash (red and white) 15% variable, and fixed carbon upwards of 51%. Seven maunds of coal taken from the lower parts of the Rampur seam gave 12½% of reddish ash—one little bit formed a clinker. Generally, the coal may be said to be of fair quality, parts very good, ignites freely, and, except that one bit clinkers, open-burning, suitable for steam purposes and of workable thickness.

It may, I think, be safely assumed that this is the Eeb seam. Such being the case the outcrop of this seam is seen to be duplicated, and this point itself is almost sufficient to prove the existence of a down throw fault (and to a certain extent locate it) to the east, since the seam dips to the west. In addition to this evidence, however, the occurrence of Talchir shales in the Modlia nala, the positions of the basement white Barakar sandstones on both sides of

the Eeb Bridge and at Telanpali, the absence of coal in the No. 1 bore-hole of the Bengal-Nagpur Railway Company (K^1 on map) and the presence of a spring near Rampur are sufficient to warrant the assumption, and determine the line of a down throw fault to the east as shown on the plan.

Horizon of the Eeb Bridge seam.

Upon what grounds the Eeb coal seam has been identified with the Durlipali shale bed I do not know, but I am certainly not of that opinion and indeed think that the Eeb seam is the lower by some 200 to 300 feet. If the exact position of the bore-holes put down by Dr. King in the Lillari valley and also that of the Bengal-Nagpur Railway Company, 'No. 3' can be ascertained, this point could, I think, be settled beyond doubt.

Conclusion.

In conclusion I would like to add that further action in this area should be directed towards the immediate exploitation of the Eeb coal seam and the completion of bore-hole No. 4 (K^4 of map) down to the Talchirs. At the same time the Bonjari and Khaliabahal beds might be followed up to the west and north, for, as I have before stated, it is not improbable that these beds will improve; and here it is necessary to add that such further exploration cannot be carried out in a satisfactory manner unless accurate topographical maps be supplied upon which data already known can be mapped and deductions drawn therefrom.

Preliminary Report *on the* Sohagpur Coal-field, *by* G. F. Reader, F.G.S., *Coal Specialist, Geological Survey of India.*

In Volume XXI, Part 3, of the Memoirs of the Geological Survey of India, Mr. Hughes describes the above coal-field, and records the

existence of the coal seams which came under his notice, and at the same time he makes such observations on each seam as his preliminary investigation would allow. The present survey is intended to collect more practical details of some of the most promising seams mentioned by Mr. Hughes, and of other seams encountered during its progress.

Object of Survey.

On page 46 of the Memoir referred to, Mr. Hughes states :—

"The main seam comes to the surface between Bargaon and Kelhauri, once in the Jamunia, thrice in the Sōn, frequently in the Bagéha, and twice in the Nargàra seams. It covers a large and easily workable area or either side of the Sōn, and it can be picked up along its strike for a distance of 10 miles. It is the seam '*par excellence*' of this part of the field."

On such a prescript I pitched my camp at Burharand and commenced operations in the neighbourhood of this seam. In amplification of the above abstract, I am now in a position to say that a good seam of workable coal crops out near Amlei in the Bagéha nala and also about a mile further south-west in the same nala. It dips about 3° to the north-west, and to judge from its strike, I am at present inclined to think that it may be correlated with a seam exposed in the Sōn 7 miles north-east of the Amlei exposure and 1½ miles north-east of Bokahi. The section of the seam is :—

Amlei seam.

AT AMLEI.

	Ft.	in.
Massive sandstone . .		
Banded ,, . . .	1	6
Fireclay shale . .	2	6
Soft coal . . .	1	5
Carbonaceous shale .	0	5
Hard coal . . .	0	6
Soft ,, . . .	2	1
Hard ,, . . .	7	0
Shaly ,, . . .	1	2
Soft ,, . . .	2	8
Carbonaceous shale .	0	2
Sandstone		
Base		

IN THE SŌN.

	Ft.	in.
Massive sandstone .		
Gritty sandstone . .	4	0
Hard coal . . .	4	8
Gritty sandstone . .	2	0

If these seams be correlated it will be seen that a thickness of 15 feet 5 inches of carbonaceous matter at Amlei (containing 13 feet

8 inches of good coal) is represented by 4 feet 8 inches of coal in the Sōn. In such case, whether the decrease in thickness is due to splitting up or actual thinning out, remains to be proved. I favour the former supposition, and indeed think that a further search in the Sōn will reveal the upper part of the Amlei seam. The analyses made by Sub-Assistant Hira Lal gave the following results:—

	AMLEI BAGÉHA.	BOKAHI SŌN.
Moisture	5·2 per cent.	Nominal.
Volatile matter	22·2	27·4
Fixed carbon	57·2	61·0
Ash	15·4	11·6

The calorimeter and large scale tests confirm these results—the evaporative power of the former exceeding 12·5 and the latter 12·9 when conducted on general samples (not dried). It is a free burning, non-clinkering, hard coal, and suitable for steam purposes.

The next most productive coal-bearing band strikes from south of Sabo in the Bagéha nala up the stream to north-east of Dhanpuri in the Nargara nala. Several pits were sunk along this strike and the following sections obtained:—

NORTH-EAST OF DHANPURI NAGARA NALA.

	Ft.	in.
Carbonaceous shale	0	4
Coal	0	4
Carbonaceous shale	0	4
„ clayey shale	0	6
Coal	2	9
Carbonaceous shale	0	6
Coal	1	0
Hard sandstone	1	7
Soft „	0	5
Hard „	2	0
Carbonaceous shale	1	2
Coal	1	10
Carbonaceous shale	0	9
Coal	2	3
Carbonaceous shale	0	7
Sandstone	1	6

WEST-NORTH-WEST OF JHAGRAHA BAGÉHA NALA.

	Ft.	in.
Coal	3	8
Carbonaceous shale	0	8
Coal	0	9
Carbonaceous shale	0	4
Coal	2	9
White sandstone	5	2

SOUTH OF SABO IN TRIBUTARY OF BAGĚHA NALA.

	Ft.	in.
Black dirt	4	0
Hard *coal*	4	3
Carbonaceous shale	0	4
Coal	0	6
White sandstone	0	4½
Shale	0	1
White sandstone	0	4½
Carbonaceous shale	0	6
White sandstone	3	0

SOUTH OF SABO IN BAGĚHA NALA.

Ft.	in.	
2′	0″	Sandstone.
2′	0″	Micaceous sandstone.
3	5	Carbonaceous shale.
1	3	*Coal.*
2	2	Carbonaceous shale.
0	9	*Hard coal.*
0	5½	Carbonaceous shale.
3	0	*Coal.*
1	10	Carbonaceous shale.
1	5	*Hard coal.*
2	6	*Coal.*
2	0	White sandstone.

Whether the above sections (Dhanpuri, Jhagraha, and Sabo) represent two or three seams, I am not yet in a position to state. Reasoning from the dip and strike of the measures the Dhanpuri section is the outcrop of one seam and the Jhagraha and Sabo sections the outcrop of another seam. Taking the sections and qualities only into consideration, however, there appear to be three seams, *i.e.*, Dhanpuri, Jhagraha, and Sabo sections; each represents a different outcrop and as such I prefer to treat of them.

Dhanpuri seam.

The Dhanpuri seam presents a most tantalizing section to a practical man: two bands of coal, each only just thick enough to be comfortably workable with a band of shale in the middle, and a clay shale roof. The question how to work this seam might well be asked by an examining Board in England—if the Board itself could agree as to what the answer should be. If, however, its section is half and half, so to speak, its quality is a little better. The average analysis of a general sample is:—

Moisture	7 per cent	Evaporative power *approximately 12*.
Volatile matter	25 " "	
Fixed carbon	53 " "	
Ash; (clinkers)	15 " "	

The Jhagraha seam certainly presents at its outcrop a fair workable section and the coal looks good. To my surprise, however, large and small scale tests gave very bad results: average ash percentage is 42, calorific power 5153 calories or 9·9 evaporative power.

Jhagraha seam.

The Sabo seam presents a better section than the Jhagraha and as regards quality also it is a good seam. Its analysis gives :—

Sabo seam.

Moisture	1 per cent.	Evaporative power 12·7 per cent.
Volatile matter . .	21·4 „	
Fixed carbon . . .	60·8 „	
Ash (little clinker) . .	16·8 „	
	100	

In addition to the above at least three other seams deserve mention. One, half a mile east of Bargaon 3 feet 8 inches thick; one, in the Bakan nala, 600 yards from its junction with the Sōn, 4 feet 4 inches thick; and one, near Rampur, in a tributary of the Katna river, 5 feet 6 inches thick, with a band of shale in the middle.

Tests have not as yet been made on these. Their thicknesses are workable and preliminary experiments point to a fair quality.

Other seams.

Summary.—In descending order the seams appear to come as follows :—

Sabo (in Bagéha nala).
Jhagraha (Ditto).
Dhanpuri (Nargàra nala).
Amlei-Bokahi (Bagéha and Sōn).
Bargaon-Kelhauri.
Rampur (tributary of Katna).
Bakan (Bakan nala near Sōn).

Of these the Sabo and Amlei-Bokahi have given workable thicknesses and very fair qualities. The Jhagraha and Dhanpuri seams have not given satisfactory results, but may be found on further exploitation to improve in quality and section respectively. The Bargaon-Kelhauri, Rampur and Bakan nala seams give workable thicknesses and preliminary experiments point to fair qualities.

Preliminary Report *on the* Geology *of the* Northern Shan States, *by* TOM D. LATOUCHE, B.A., *Superintendent, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTORY.

The tract of the country described in the present report is that portion of the northern Shan States which lies along the line of railway now under construction between Mandalay and the Kunlon ferry on the Salween; that is, between the 22nd and 23rd parallels of north latitude and extending from about the 96th to a little beyond the 98th degree of east longitude. This route had been traversed before by Dr. Fritz Noetling, who in 1890 visited and reported on the coal-fields of Lashio and the Nam Ma valley in the eastern portion of the area.[1] Dr. Noetling proved the presence of lower silurian rocks near the western edge of the hills, between the 22nd and 26th miles on the cart-road, then being constructed from Mandalay to Lashio, and described some of the fossils he obtained from them in a

[1] Records, G. S. I., Vol. XXIV, Part 2, p. 99.

short paper in the *Records.*[1] The most important was a gigantic form of the cystidean *Echinosphærites*, to which he gave the name of E. Kingi. I had a great advantage over Dr. Noetling in being able to avail myself of the numerous cuttings along the railway, which for the greater part of the distance runs close to the cart-road. Moreover, I was not hampered with considerations of economic geology, but was able to devote myself entirely to the working out of the stratigraphy along the routes. Consequently I was able to add considerably to the number of localities in which fossils are obtainable, and to prove the existence of a series of palæozoic formations in addition to the lower silurians discovered by Dr. Noetling. When I left the line of the railway, however, and attempted to penetrate into the country on either side, I experienced the same difficulty as Dr. Noetling, in finding outcrops of solid rock. The enormous thickness of clay, derived from the weathering of the prevailing limestones, with which the rocks are covered, is well seen in many of the railway cuttings. Cliff sections are rare, and the rocks forming them are often concealed by masses of stalactites, while the rocks in the beds of the streams are nearly always concealed by a coating of calcareous tufa, deposited by the lime-laden waters, and often several feet in thickness.

The physical features of the hills have already been described by Dr. Noetling in the report published in Vol. XXIV of the Records, Geological Survey, above referred to.[2] Since I followed the same routes I have nothing to add to his description. Further detailed examination of the country to the north and south of the railway, with the help of more accurate maps, and on a larger scale than those now obtainable, is required before the orography of the district can be fully discussed.

II.—List of Formations and Fossil Localities.

The formations met with along the railway and cart-road between the foot of the hills at Sedaw and the Salween at Hsopket, east of Lashio, are the following, in descending order:—

[1] Records, G. S. I., Vol. XXIII, Part 2, p. 78.
[2] p. 101.

No.	Period.	Description of beds.	Local Name.	No.	Localities.	Latitude, approx.	Longitude, approx.
						° ′ ″	° ′ ″
11	Recent	Valley gravels and alluvial deposits with numerous land and fresh-water shells.	...	...	Nam Tu (Myituge) valley near Hsi Paw, and generally in the larger river valleys.	...	...
		Older gravels and boulder beds.	...	...	Lower slopes of hills in the neighbourhood of Hsi Paw.	...	...
		Red or yellow clays, often of great depth, and sometimes consolidated by the infiltration of carbonate of lime into a hard rock, containing land and fresh-water shells.	...	...	Railway cuttings near Naurighkio.	22 20 0	96 51 0
					3 miles east of Lwekaw	22 33 0	97 11 0
		Similar clays hardened by infiltration of iron oxide, laterite, occasionally sufficiently rich to be worked as an iron ore.	...	...	Near Waboye village	21 58 0	96 25 0
10	Tertiary	White and yellowish sandstones with grey and brown clays and coal seams.	...	...	Lashio. Nam Ma Valley.	...	...

9		Red and brown sandstones with numerous bands of red clay and coal shales.	Namyao beds .	1	Mandalay-Kunlon Railway, about a mile above junction of Namyao and Nam Ma near Se Ing.	22 43 0	97 34 0
8	Devonian .	Grey and olive shales with concretionary masses of dark blue limestone.	Kyinsi beds .	2	Mandalay-Kunlon Railway, west end of deep cutting at Kyaukkyan, about 6 miles west of Naunghkio.	22 18 0	96 46 0
				3	Mandalay-Kunlon Railway about a mile west of Kyinsi village, near junction of Namsim and Nam Tu.	22 33 0	97 14 0
					Mandalay-Kunlon Railway between Waboye village and Maymyo.	...	...
7	(?) Upper silurian	Thick beds of limestone, generally siliceous, or calcareous sandstones, white or grey, with subordinate bands of argillaceous shale or "Fuller's earth."	Maymyo beds .	4	Mandalay-Kunlon Railway, spoil pits about 5 miles north-east of Maymyo.	22 4 0	96 34 0
				5	Mandalay-Lashio cart-road, mile 55, close to village of Wetwun (Wenwi).	22 6 0	96 39 0

No.	Period.	Description of beds.	Local Name.	No.	Localities.	Latitude, approx.	Longitude, approx.
						° ′ ″	° ′ ″
7	(?) Upper silurian	Thick beds of limestone, generally siliceous, or calcareous sandstones, white or grey, with subordinate bands of argillaceous shale or "Fuller's earth."—*contd.*	Maymyo beds	6	Mandalay-Kunlon Railway, spoil pits 2 miles north of Gokteik station.	22 22 30	96 58 0
				7	Mandalay-Kunlon Railway, about 3 miles west of Lwekaw.	22 33 0	97 6 0
				8	Mandalay-Lashio cart-road, mile 169.	22 44 0	97 42 30
				9	Bridge on Lashio-Kunlon road, about 4 miles north of Lashio.	22 59 30	97 49 30
				10	Isolated hill, about a mile west of Mongyaw	23 1 30	98 7 0
				11	Mandalay-Kunlon Railway, 2nd cutting, below mile 21. Scarp below Zebingyi village.	21 54 0	96 20 30

6	Upper silurian .	Black calcareous shales with bands of hard black, or dark grey limestone.	Zebingyi beds.	Graptolite beds.	12	Mandalay-Kunlon Railway, cutting about a mile east of Zebingyi station.	21 54 0	96 22 0
					13	Bed of stream about half a mile north of Pyinsa village, Mandalay-Lashio cart-road, mile 28.	21 52 0	96 24 30
					14	Mandalay-Lashio cart-road, mile 32, about a mile north of Thondaung rest-house	21 54 0	96 24 30
					15	Mandalay-Kunlon Railway about half a mile east of Thondaung (Waboye) station.	21 56 30	96 25 30
5		Soft, yellow, sandy shales and sandstones with nodular beds of limestone.		Trilobite beds.	12	See above.		
					14	See above.		
					16	Mandalay-Lashio cart-road, crest of ridges west of Pyinsa village.	21 52 0	96 23 30
					17	Mandalay-Lashio cart-road, mile 88½, east side of Gokteik gorge, above Chaungyou rest-house.	22 22 0	96 53 30
					18	Mandalay-Kunlon Railway, cutting about 5 miles east of Pyaungaung.	22 31 0	97 3 30

No.	Period.	Description of beds.	Local Name.	No.	Localities.	Latitude, approx. ° ′ ″	Longitude, approx. ° ′ ″
4	Lower silurian	Grey and olive green shales and limestones, weathering into soft sandy shales.	Naungkangyi beds (? Bala or Caradoc).	19	Hills 2 miles north of Maymyo on path to Naungkangyi.	22 3 0	96 30 30
				20	Left bank of river north of Nawughkio, on path to Nahung village.	22 21 30	96 50 0
				21	Mandalay-Lashio cart-road zigzags between miles 84 and 86, Gokteik gorge.	22 21 0	96 52 30
3		Flaggy limestones separated by bands of shale and clay, occasionally carbonaceous.	Nyaungbaw beds.	22	Mandalay-Kunlon Railway, mile 19, below Zebingyi.	21 53 30	96 19 30
				...	Mandalay-Lashio cart-road, mile 22 near Nyaungbaw rest-house	21 51 0	96 20 0
2		Dark red calcareous shales.	Red crinoid beds (Pyintha beds, Noetling).	23	Mandalay-Kunlon Railway, between 3rd and 4th reversing stations above Sedaw.	21 53 0	96 18 0
				24	Mandalay-Lashio cart-road, miles 25 to 26 on ascent from Nyaungbaw to Pyinsa.	21 51 0	96 23 0
1		Massive and flaggy limestone traversed by numerous veins of calcite.	Sedaw limestone (Mandalay limestone, Noetling).	...	Zigzags on railway above Sedaw.		

It is very seldom, indeed, that the actual contact between any two of these formations can be seen. Everyone of the beds, from the red sandstones downwards, has been greatly crushed, folded, and faulted and the dips often vary considerably both in direction and amount within the space of a few yards. Thus it is impossible to say whether the beds mentioned above form a continuous conformable sequence or not. There are some indications of an overlap of the upper silurian limestones (No. 7) on the underlying formations, though there is no direct evidence of an unconformability. Thus the black graptolite shales of Zebingyi (No. 6) were not found anywhere to the east of Maymyo, though the trilobite beds (No. 5) which underlie them in the Zebingyi sections are found immediately beneath the white limestones in the Gokteik gorge, and again still further to the east near Pyaunggaung. It is quite possible, however, that the graptolite beds were originally merely a local deposit.

Generally speaking, there is a distinct zonal arrangement of the different formations, the oldest occurring along the western edge of the hills, while as we proceed eastwards newer formations are successively crossed. The general strike is between N.-N.-E. and E.-N.-E., but it varies greatly within short distances. This is also the general direction of the railway and cart-road, so that they often run for several miles on one and the same formation.

III.—Description of formations.

1.—*Sedaw limestones.*

This is the "Mandalay limestone" of Noetling, but I am not at all sure that the limestone which forms the Mandalay hill and other isolated hills in the Irrawaddy valley, between Mandalay and the edge of the Shan plateau, is the same as that found on the steep ascent from Sedaw. It is possible that the limestone in the plain belongs to a much higher position in the series, but in the absence of recognizable fossils it is impossible to be sure of this. The Sedaw beds consist of hard dark blue or grey limestones in thick beds, traversed by numerous veins of white calcite, greatly crushed and folded. In the railway cuttings on the zigzags above

Sedaw, sections of *bivalves*, *gastropods*, and *crinoid* stems are common on the weathered surface of some of the beds, but cannot be extracted in a sufficiently well preserved condition for identification.

2.—*Red crinoid beds.*

These consist of dark red calcareous shales greatly crushed, and traversed by numerous gliding planes, slicken-sided surfaces being very common, with veins of calcite running through them in all directions. Everywhere they contain scattered joints of small crinoid stems, usually not more than ⅛ or ¼ inch in diameter, but rendered conspicuous by the contrast of the white calcite of which they are composed, with the dark red colour of the rock. Hand specimens showing these crinoid stems resemble very closely the red crinoid shales at the base of the carboniferous series in the Central Himalayas,[1] but the latter are undoubtedly newer than upper silurian, while these are lower silurian. It is in these beds (called by Dr. Noetling the Pyinsa group), that *Echinosphærites Kingi*, described by him in Vol. XXIII, Part 2, of the *Records*, is found, but it appears to be very local in its occurrence; and although very good sections of the red crinoid beds are exposed in the railway cuttings above Sedaw, I did not come across a single specimen of it. Fragments of *Orthoceras* are also found in these beds and are locally numerous.

3.—*Nyaungbaw beds.*

The red crinoid beds pass upwards into a considerable thickness of flaggy limestones in regular layers, separated by bands of clay or shale. Occasionally the latter are somewhat carbonaceous. Fossils are fairly numerous in places, and consist mostly of *Orthoceras* and other cephalopods, generally in fragments, *crinoid* stems, and fucoid impressions. Near the village of Nyaungbaw, at mile 22 on the Lashio cart-road, Mr. Datta found some fairly well-preserved specimens of *crinoids* showing portions of the calyx and arms as well as fragments of the stem. These are associated with *Orthoceras* and appear to be quite local in occurrence. I could not find them in the cuttings along the railway, where these beds are very well exposed, but at the nineteenth mile *Orthoceras* occurs in considerable numbers.

[1] Griesbach, Mem. G. S. I., Vol. XXIII, p. 61.

4.—*Naungkangyi beds.*

In the railway cuttings below Zebingyi the beds just described are followed immediately by a bed containing upper silurian fossils, but in the Gokteik gorge, a long way to the east, another outcrop of lower silurian beds is found, which is not represented to the west of Maymyo, though it occurs in the hills a couple of miles to the north of that place. The beds consist of a considerable thickness of grey calcareous sandy shales, with bands of limestone, sometimes weathering into soft, reddish yellow, sandy shales. They contain great numbers of casts of *Orthis*, *Strophomenas*, etc., with single plates of cystideans, some of which resemble very closely *Mimocystites bohemicus* (Barr.), from the stage D^2 (=Bala or Caradoc) of Bohemia.[1] The manner in which the casts of *Orthis* are matted together on the surface of the slabs, and the general appearance of the rock, reminds one very strongly of the Caradoc beds of Shropshire.

ZEBINGYI BEDS.

5.—*Trilobite beds.*

In the neighbourhood of Zebingyi the flaggy limestones of the Nyaungbaw series are followed by soft, yellow, sandy beds with nodular bands of limestone, containing large numbers of *Orthoceras* and fragments of *Trilobites*, with a few small *lamellibranchs* and *brachiopods*. The *Trilobites* are not very common and are generally badly preserved. In the Gokteik gorge similar beds occur containing heads of *Eucrinurus punctatus*, east of *Orthis* and *Petraia*.

6.—*Graptolite beds.*

These consist of black calcareous shales with bands of hard dark grey or black limestone containing large numbers of *Graptolites*, all of the monoprionidian order, though they are frequently so crowded together on the surface of the rock, that it is difficult to make out whether double forms occur or not. A small

[1] Barrande, Syst. Silur. de Boheme, Vol. VII, pl. 28.

Tentaculites closely resembling *T. elegans*, Barr.,[1] is very common and is a most useful fossil in tracing out the distribution of these beds, for it appears to be almost entirely confined to this horizon and is not easily destroyed by weathering, so that it can be recognized even in outcrops where the rock has been reduced to a soft clay.

The graptolite beds are only a few feet in thickness and occur only in this section west of Maymyo.

7.—*Maymyo beds.*

The graptolite beds are followed by massive white limestones, always characterized by the presence of a considerable amount of siliceous material; in fact, the rock is sometimes rather a calcareous sandstone than a limestone. These rocks may be traced almost continuously from near Thendaung (Waboye) station about eight miles west of Maymyo to the Salween,—a distance of nearly 200 miles. They are not very fossiliferous, but casts of small *gastropods* and a *lamellibranch*, probably a *Pterinea*, are numerous in some places, and help considerably in identifying these rocks in the small outcrops, which are often all that can be seen of them protruding through the thick covering of red clay. In a few places beds of argillaceous shales resembling Fuller's earth are found among these limestones, but I could never find them in actual contact; so that I could not discover whether the shales occur at any particular horizon in the limestones, or not. These shales contain a fairly rich fauna including a small *Lingula*, many *bivales*, and a fossil that looks like a *Theca* or *Hyolithes*, but none of them appear to be very characteristic. They may be either uppermost silurian or perhaps devonian.

The thickness of the limestones must be very great. They form the great precipices seen on either side of the Gokteik gorge and many lofty scarps in the neighbourhood of Lashio, but they are so much cut up by faults that it is impossible to form any estimate of their true thickness.

8.—*Kyinsi beds.*

The white limestones are succeeded by a band of shales of no great thickness with concretionary masses of hard blue limestone.

[1] Barrande, op. cit., Vol. III., pl. 14.

Both shales and limestone are highly fossiliferous, but in the latter the fossils only appear as sections on the weathered surface of the rock and complete specimens cannot be extracted. In the shales, on the other hand, the fossils can be easily extracted and are of great variety. Among *lamellibranchs* a *Pecten* is very common, and a small *Conocardium* occurs. A small *gastropod*, probably *Murchisonia*, also occurs in large numbers. The fossils collected have not yet been specifically determined, but it seems probable that the beds are devonian. They contain no typically silurian or carboniferous fossils, so far as I have been able to judge from a cursory examination, nor can any of them be referred with certainty to the mesozoic period, though I thought, when I first discovered them, that the beds might possibly be jurassic. The presence of *Conocardium* seems to point to their being upper palæozoic.

9.—*Namyao beds.*

The shales just described are followed by a great thickness of red beds, consisting of rapidly alternating layers of sandstone and shales or clays. These beds were described by Dr. Noetling as "red sandstones of undetermined age." They apparently rest conformably upon the grey fossiliferous shales near Kyinsi, but to the east of this the latter appears to be absent, and the red beds rest upon the white limestones (No. 7). Excellent sections of them are seen in the railway cuttings along the Namyao valley, between Hsi Paw (Thibaw) and Lashio, but fossils appear to be very rare. I obtained a few from one locality near the junction of the Namyao with the Nam Ma, but all are in a very fragmentary state, and none of them, I am afraid, can be specifically determined. They resemble, however, to some extent, the fossils from the grey shales below, and it seems probable that these and the red beds belong to one series. If this is the case, the whole of the mesozoic period is quite unrepresented in the portion of the hills traversed by the Mandalay-Kunlon Railway, for the only rocks that occur on this route, higher than the red sandstones, are of tertiary age. Some of these red sandstones form an excellent building stone.

10.—*Tertiary formations.*

The tertiary system in the northern Shan States, with the

accompanying coal seams, has been described in detail by Dr. Noetling.[1] The route which I followed did not cross these beds anywhere. They seem to be entirely confined to the river valleys and to be of very small extent. No doubt when the railway is opened to Lashio the coal will be made use of to some extent, though it is doubtful whether it will be worth exploiting on a large scale.

11.—*Recent formations.*

The chief superficial feature of the plateau, from a geological point of view, is the thick mass of clay, generally bright red in colour with which, practically, the whole of the country is covered. It has mainly been derived, in all probability, from the weathering of the limestones, principally the white and grey, sandy limestone of the upper palæozoic era, which is the prevailing rock. In the railway cuttings this deposit is often seen to reach a thickness of 40 or 50 feet. In many places the clay has been consolidated, by the infiltration of carbonate of lime derived from springs, into a tough rock, containing recent land and freshwater shells, such as *Helix*, *Limnæa*, *Neritina*, etc., which may be found still living in large numbers in the cultivated flats near the banks of the larger rivers. Numerous pisolitic granules of iron oxide are scattered freely through the clay, and in some places the amount of iron becomes so great, that the rock has been used as an ore for smelting.

The carbonate of lime leached out from the rock is partly carried off by the streams, and partly redeposited in their channels, forming thick beds of calcareous tufa. Wherever rocky scarps are found, they too are usually covered with a thick curtain of the same material. The "natural bridges" in the Gokteik gorge are to a great extent formed of it, and its cavernous nature has proved a considerable obstacle to the engineers engaged on the construction of the great viaduct there. In many of the rivers it forms regular dams or weirs, stretching horizontally across the stream, and so regular that they might be thought to be artificial. The presence of this calcareous tufa in the streams, although it adds much to their picturesqueness, is a great drawback from a geological point of view, for the rocks are entirely concealed by it in most cases, and nothing can be seen of them. The deposit is sometimes of great thickness, as, for

[1] Records, G. S. I., Vol. XXIV, Part 2, p. 105, et seq.

instance, in a spur cut through by the railway between Lwekaw and Kyinsi, on the Namsim, where the cuttings show it to be at least 50 or 60 feet thick.

Beds of recent alluvium are not often met with in the portion of the plateau which I crossed. There are a few narrow patches of it in the valleys of the larger rivers, notably in the valley of the Nam Tu (Myitnge) near Hsi Paw, where there are also a few patches of older alluvium containing large well rounded boulders, mainly derived from the red sandstones, on the lower slopes of the surrounding hills, probably the remains of old river terraces.

IV.—STRATIGRAPHICAL DETAILS ALONG THE ROUTE TAKEN.

From Sedaw, a small village at the foot of the hills about 15 miles to the south-east of Mandalay, the line rises by a series of zigzags, directly up the hillside, to a height of about 600 feet above the plain, passing through the dark blue and grey limestones of the Sedaw beds. The dip of these at the foot of the ascent is to the west-south-west at about 50 degrees; in fact, the outer edge of the plateau here is a dip slope. The direction of dip does not, however, remain constant for more than a short distance. Between the second and third reversing stations it is at first northerly, and then again south-westerly, always at fairly high angles. The folds, of which only small portions can be seen at one time in the cuttings, are probably in the form of domes of no great lateral extent, so that the direction of dip varies greatly within short distances. Just below the third reversing station, at a height of about 600 feet above the plain, the red crinoid beds are met with. The actual line of contact is concealed, and the two formations are dipping in quite different directions, that of the limestones being north at about 20 degrees, while the red crinoid beds dip east at 45 degrees. In spite of this difference of strike, I do not think that there is any unconformability. The whole series probably forms an anticlinal with its axis nearly north and south, but the general direction of the fold is obscured locally by minor cross-folds.

The red crinoid beds are well seen between the third and fourth reversing stations, where there are some deep cuttings through them. The only fossils I could find in them, are small fragments of crinoid

stems and one badly preserved *Orthoceras*, the whole interior of which is filled with white crystalline calcite, but the position of the siphuncle is still discernible.

These beds pass upwards into a thick series of flaggy limestones in regular layers, separated by bands of clay or shale, very well exposed in the cuttings between the 18th and 20th miles. Near the base of these, two or three bands of red shales are intercalated, exactly similar to the thick crinoid beds below and also containing crinoid stems. Higher up, at the 19th mile, numerous specimens of *Orthoceras* occur in a small quarry close to the line; the dip here is northerly at about 11 degrees. In a cutting immediately above this some carbonaceous shales are interstratified with the limestones.

These limestones and shales are also well seen along the cart-road, some few miles to the south, in the neighbourhood of Nyaung-baw. At the 22nd mile, about a mile and a quarter below the rest-house, they contain fragments of a large *crinoid*, some of the specimens showing the calyx with the arms attached, also numerous specimens of *Orthoceras*.

On the railway these beds extend to about the 20th mile. They are greatly disturbed and faulted, and the same beds may be repeated more than once. Above the 20th mile there is a low but well-defined, scarp, about 150 feet in height, at the top of which is a level plateau in which the village of Zebingyi stands. The railway skirts this to the north, exposing good sections. At the base a band of dark grey limestone, rather nodular, is seen containing numerous specimens of *Orthoceras* and an occasional *Trilobite* (No. 5). The dip here is to east-north-east at about 15 degrees. This band is followed by black calcareous shales (No. 6) containing numerous specimens of *Graptolites*, matted together on the surface of the layers. With these occur enormous numbers of a small fossil, the nature of which I was at first unable to determine. They are in the form of minute spines, from about $\frac{1}{4}$ to $\frac{3}{4}$ inch long, and $\frac{1}{6}$ to $\frac{1}{8}$ broad. A furrow runs for about half the length from the broader end down the centre, and the whole fossil is beautifully ornamented with regular transverse striæ. I thought that they might be a species of *Theca* or *Hyolithes*, but I find that they correspond most closely to *Tentaculites elegans* (Barr.). The figure given in Vol. III, Pl. 14, of Barrande's Silurian System of Bohemia might have been taken from one of the Zebingyi slabs. These fossils belong to the stages G and H or upper silurian

of Barrande's classification, and with the *Graptolites*, which appear to be all confined to the genus *Monograptus*, afford, I think, sufficient evidence that these beds belong to that epoch.

The black shales at Zebingyi are followed by white, or light grey limestone (No. 7), in which I could find no fossils in this locality, but a few ill-preserved fragments of *crinoid* stems. The surface of the Zebingyi plateau is formed of this rock. The limestones, where first seen, are dipping in the same direction, *i. e.*, easterly, as the graptolite beds, and apparently rest conformably upon them.

Proceeding along the railway to the east of Zebingyi station, the white limestones are seen for about a mile dipping in a north-westerly direction. It is thus evident that the rocks underlying the plateau form a synclinal. About the 23rd mile the graptolite beds are brought up again, dipping N. 40. W. at an angle of 15 degrees. They are succeeded below, by a band of soft yellow shales with concretionary bands of hard limestone (No. 5). Here *Trilobites* are more numerous than in the Zebingyi scarp, but they appear to occur only in the soft beds, and are difficult to preserve. The limestones immediately beneath contain large numbers of *Orthoceras*, but mostly in a fragmentary state.

Beyond this the line runs by a succession of severe gradients up the side of a steep ridge, on which the lower flaggy limestones and shales (No. 3) are well seen. They are greatly disturbed and frequently dip at high angles, generally in a north-westerly direction. They appear to contain nothing but a few *crinoid* stems. About a couple of miles from the base of the ridge the red crinoid beds (No. 2) appear beneath the flaggy limestones, but are not well seen, as the latter quickly bend over again to the east.

The axis of the Zebingyi synclinal appears to be inclined to the north, so that on the cart-road about three miles to the south of Zebingyi the graptolite and trilobite beds are not met with, but the whole space between Nyaungbaw and the foot of the high ridge east of Zebingyi is occupied by the flaggy limestones and shales (No. 3) with *Orthoceras*. At the foot of the ridge the red crinoid shales are again brought to the surface, dipping in a west-north-west direction. At first they occur as bands of only a few feet thick in the limestones, exactly as in the section above the fourth reversing station on the railway; but a little higher up, between the 25th and 26th miles, there is a very thick band

of them. It was at this locality that Dr. Noetling discovered the lower silurian cystidean *Echinosphærites Kingi*, and numerous spcimens may be found along the road a little below the 26th mile, associated with *Orthoceras* and fairly well preserved *crinoid* stems.

These beds are succeeded below by hard limestones, probably the same as those exposed in the zizgags above Sedaw (No. 1), which extend to the crest of the ridge to within a mile of Pyinsa village, from which Dr. Noetling named the series.

Immediately after crossing the crest of the ridge, and within a few yards of the hard limestone, the soft upper silurian trilobite beds are again found, highly disturbed, but with a general north-easterly dip. They are evidently faulted down against the lower silurian limestones. To the east, close to the village of Pyinsa, the graptolite beds are formed overlying them, in the bed of a small stream, that crosses the road immediately north of the village, and dipping steadily to east-north-east at an angle of about 15 degrees. The road here turns to the north and runs along the crest of the ridge following the strike of these beds, which are exposed at two or three places, *viz*., near the 29th mile, and again about a mile north of Thondaung rest-house near mile 32. A short distance beyond this, at the village of Thingunaing, they pass under the upper palæozoic white limestones, which form another well defined scarp to the east of the road, but they are again well exposed in the same strike in a cutting on the railway about half a mile above Thondaung (Waboye) station. Well preserved specimens of *Graptolites* and *Tentaculites elegans* with a small bivalve, may be obtained in the spoil pits along the line at this locality.

The Pyinsa fault appears to die out in this direction, passing into an ordinary anticlinal fold, which is well seen in the cuttings on the ascent between Zebingyi and Thondaung station. The railway runs practically along the crest of the fold.

Above Thondaung station the graptolite beds pass beneath the white sandy limestones (No 7), which extend all the way to Maymyo, with a general easterly dip, and form the plateau on which the station is built. In some of the cuttings casts of small gastropods are found in the limestone, but for the most part it appears to be unfossiliferous.

To the north of Maymyo the white limestones extend for about two miles to the foot of a range of low-rounded, jungle-covered hills.

Sections of the rocks composing these are seen on the path to the village of Naungkangyi and they are found to consist of soft sandy shales, somewhat similar in appearance to the trilobite beds, but containing a very different assemblage of fossils. No *Graptolites* or *Trilobites* were found in them, nor could I find any specimens of the small *Tentaculites elegans*, whose remains are so characteristic of the graptolite beds. Instead of these there are numerous specimens of *Orthis* and of plates of a small cystidean closely resembling *Mimocystites bohemicus*, a Caradoc or Bala fossil. These beds dip to the south-east at angles of 40 to 50 degrees and the white limestones are apparently faulted down against them.

To the east of Maymyo the white limestones extend both along the railway, and cart-road to, and beyond the village of Wetwun. Casts of small gastropods occur in a spoil-pit on the railway about five miles from Maymyo. Just beyond Wetwun, at the 55th mile on the cart-road, a band of argillaceous shale or Fuller's earth is badly exposed at the side of the road, containing numerous fossils, including many lamellibranchs, casts of a small *Orthis* or perhaps *Atrypa*, and a fossil, badly preserved, resembling *Theca* or *Hyolithes*. A *Fenestella* also occurs. The relations of these shales to the limestones cannot be made out, but they probably form a band in the latter.

Beyond Wetwun nothing is seen along the road except an occasional, very small outcrop of white limestones, until the 73rd mile is reached, near the village of Kyaukkyaw, where the railway and cart-road cross a well-defined scarp running north and south. Here there is a deep cutting through the limestone, in which the intense crushing which the rocks have undergone, can be well studied. Slicken-sided surfaces are numerous, highly polished and covered with a thin red glaze, and the body of the rock is so crushed that it breaks into small fragments when struck with a hammer—a condition made use of by the railway engineers, who convert the rock, at the expense of a few charges of dynamite, into heaps of ballast, ready broken, for the railway.

Immediately to the west of the deep cutting, there is a smaller one, in which some highly fossiliferous shales (No. 8) are exposed. These dip to the east and appear to pass under the limestones, but as I found precisely similar fossils in some shales, to be described presently, near Hsi Paw further to the east, where they occur at the top of the limestones, it is probable that they are faulted down

against the latter in the Kyaukkyan ridge. The fossils in the shales include numerous casts of *Pecten*, a small *Conocardium*, and other lamellibranchs, which have not yet been determined. The shales rest upon hard dark blue limestones in which fossils are numerous, which appear only as weathered sections on the surface of the rock.

Beyond Kyaukkyan a plateau formed of the white limestones extends *viâ* Nawnghkio to the edge of the Gokteik gorge, where the rocks bend over and plunge into the gorge with a steady easterly or east-south-east dip of about 30 degrees. The rocks are greatly crushed and full of small faults and gliding planes. On the opposite (north-east) side of the gorge the cliffs are entirely composed of the white limestones, which must be of enormous thickness unless they are repeated by faulting. Near the bottom of the gorge the rocks are almost entirely covered with a thick deposit of cavernous calcareous tufa of which the well-known "natural" bridges are to a great extent composed.

The cart-road crosses the gorge some miles above the railway-crossing, and the cuttings along it afford good sections of the rocks beneath the white limestones. For the first two or three miles limestone is seen at intervals ; then at the short cut above the eighty-fourth mile there are some soft yellow, sandy beds, containing badly-preserved fragments of *crinoid* stems, probably the representatives of the trilobite beds of Zebingyi (No. 5). These are again exposed on the eastern side of the gorge, just above Chaungow rest-house, at mile 88½, where I found specimens of *Encrinurus punctatus* in them, as well as numerous casts of *Orthis* and *Petraia*. These are followed beneath by grey, sometimes purple, calcareous shales and limestones, which are well exposed on the zigzags along the road, between the 84th and 86th miles. In places, notably at mile 85, these rocks are crowded with fossils, mostly casts of *Orthis* and *Strophomena*. The cystidean plates found in the shales north of Maymyo also occur here in considerble numbers, and I think there is no doubt that these beds are identical with those of Naung-kangyi (No. 4). The shales and limestones dip east-south-east at about 30 degrees and continue to the bottom of the gorge. They are seen again on the ascent near Chaungzow rest-house, but on this side I could find no fossils in them.

The same beds occur some miles higher up the western branch of the river that flows through the gorge, on a path that crosses it due

north of Nawnghkio, but are very badly exposed and the fossils are quite fragmentary.

Returning to the eastern side of the gorge the yellow trilobite beds above Chaungzow are found to be followed by the white limestone I searched for the black graptolite beds here, but could find no trace of them. From the edge of the gorge the limestones extend for a long distance along the road; in fact, hardly any other rock is seen for some twenty miles. In a spoil-pit on the railway, two miles north of Gokteik station, numerous casts of small gastropods and a little bivalve probably a *Pterinea* occur in the limestone, and within a few yards there is a small outcrop of argillaceous shales, similar to those at Wetwun, containing a few fossils among which a *Lingula* (?) is most common. Here again the relations of the shales to the limestone cannot be made out. A short distance further up the line, at mile 89½ on the cart-road, the shales and limestones are seen in contact, but are greatly disturbed and evidently faulted against each other. Between Pyaunggaung (mile 105) and Lwekaw (mile 116) on the cart-road, nothing but limestone is seen, the road running along the strike of the beds, which dip generally to east-south-east. But on the railway, about five miles beyond Pyaunggaung, there is an outcrop of very soft sandy beds, full of fossils, including *Fenestella retiformis* in large numbers, *Encrinurus punctatus*, *Strophomena*, *Orthis*, and many *crinoid* stems. These beds are quite isolated, but they dip apparently beneath the white limestones. Further on, about three miles west of Lwekaw, a band of shale occurs in the limestone, containing minute bivalves and fragmentary plant remains. Some of the shales are here distinctly carbonaceous.

Beyond this nothing further is seen, up to the 123rd mile on the cart-road, about a mile west of the village of Kyinsi. Here some light grey shales with nodular bands of blue limestones are exposed in the railway cuttings, containing the same assemblage of fossils as at Kyaukkyan. The shales rest upon thick dark blue concretionary limestones, the whole dipping north-north-east at 20 to 30 degrees, and fossils also occur in the limestones, only showing as at Kyaukkyan on the weathered surface of the rock. The white limestone occurs in the jungle on the southern side of the cart-road, which runs here close to the railway, and apparently dips beneath the blue limestone and shales, but the actual contact is not seen.

A few hundred yards to the east of the fossiliferous shales, but separated from them by a blank space, a very different series of beds is seen. These are soft red and green clays interstratified with thick beds of soft red and brown sandstones. Where first seen they are dipping north at from 40 to 50 degrees, but on following the beds along the railway beyond the bridge over the Namsim, they are found to be greatly disturbed and folded. To the east of this the valley opens out into a broad level plain covered with rice fields, through which the Nam Tu (Myitnge) flows, and no rocks are visible. Where the hills close in again, however, to the east of Hsi Paw, the red sandstones and shales are again met with, thrown into narrow folds striking north-east along the valley of the Nam Tu, and very well exposed in the railway cuttings through the spurs bordering the river. The sandstones are occasionally hard enough to form an excellent building stone. They occupy the whole valley of the Nam Tu up to its junction with the Namyao, or Lashio river and continue up the valley of the latter to about five miles above its junction with the Namma below Se Ing rest-house, where they are faulted against the white limestones. The red sandstones are also seen on the cart-road between Hsi Paw and Kontha rest-house, but no good sections are exposed. At Se Ing the limestones form a narrow gorge through which the river flows for several miles.

About a mile above the junction of the Namyao and Namma, I found in one of the railway cuttings a few fragmentary fossils in the red beds, mostly lamellibranchs. They have a certain resemblance to some of the fossils in the Kyinsi shales and it seems probable that the latter with the red sandstones form one series. From a cursory examination of the fossils it appears not unlikely that the whole sequence may be devonian. Fossils must be very rare in the red beds, for although I searched carefully I found none except in this one locality.

Higher up the valley of the Namyao, limestone is the prevailing rock, but the river runs along the boundary between it and the red sandstones, and the latter are occasionally seen in the railway cuttings. The actual junction is not seen anywhere, and I could not find the Kyinsi fossiliferous shales, but the whole country is covered with dense jungle and soft beds of that description are apt to be concealed.

The Namyao in this portion of its course affords many fine examples of the natural dams or weirs of calcareous tufa already men-

tioned. They succeed each other at intervals of a few hundred yards all the way up the river and are of very various heights, from a few inches up to several feet. Some five miles above Se Ing they are especially numerous and resemble a huge salmon ladder. At the top is a very fine waterfall the whole face of which is covered with tufa. These dams take the place of the rapids in an ordinary river, but it is difficult to see how the growth is started, for one would expect it to be washed away as quickly as it was formed in the broken water of a rapid. From the appearance of the fresh deposit, which is often of a vivid green colour, I suspect that it is to a great extent organic in origin and that it is built up by minute algæ much in the same way in which a true coral reef is formed.

The white limestone continues along the valley of the Namyao to, and beyond Lashio; in fact, it extends as far as the Salween, but it is generally concealed by recent clays. There are no railway cuttings along this portion of the route and very little of the rocks can be seen. About four miles to the north of Lashio, where the road to the Kunlon ferry crosses the Namyao, a small patch of shale crops out containing very ill-preserved fragments of plants; and near the village of Mongyaw at the head of the valley some minute rounded bodies occur in the limestone which may be organic, but beyond these I could find no fossils whatever. The red sandstones appear cupping the hills to the south of the valley between Mongyang and Mongyaw, but do not contain any fossils, so far as I could see. Beyond Lashio the road to Kunlon runs practically along the strike of the rocks and nothing can be seen of the formations lying to the north or south of the route.

Notes *on the* Geology *of the* country *along* the Mandalay-Kunlon Ferry Railway Route, Upper Burma, *by* P. N. DATTA, B.SC., (London), F.G.S., *Deputy Superintendent, Geological Survey of India.*

The projected railway; its general direction from Mandalay.

The projected line of railway from Mandalay to the Kunlon Ferry on the Salween in Upper Burma, passes through Maymyo, the hill station of the Lieutenant-Governor of Burma, Thibaw (Hsi Paw), and Lashio, the head-quarters of the Superintendent of the northern Shan States. There is a cart-road from Mandalay as far as Lashio, and the railway has followed close to this old cart-road as far as Thibaw. From Lashio there is no cart-road, but only a mule-track as far as the Kunlon Ferry.

Extent of route traversed.

This line of railway, the first section of which, *i.e.*, from Mandalay to Maymyo, a distance of about forty miles, was to be opened on the 1st of April this year, runs from Mandalay in a general north-east by east direction, the first fifty miles or so being in the Mandalay District, and the rest in the adjoining northern Shan States. As I, however, went only a few miles beyond Thibaw (Hsi Paw), *i.e.*, about 140 miles by the cart-road from Mandalay, my examination of the ground extends therefore to the neighbourhood of Thibaw only.

From Mandalay to Tonbo, which is ten miles south-east of Mandalay, the railway runs over a plain which shows no exposures of solid rock, the hills commencing near Tonbo.

Extent of plain eastwards of Mandalay.

Due east of Mandalay the plain extends for about 5 miles or less, the limestone composing the foot hills here being a continuation of those seen in the neighbourhood of Tonbo, the beds striking here very nearly north and south.

Mandalay Hill: its probable age.

The hillock called Mandalay Hill just north-east of the Mandalay Palace is composed mostly of crystalline limestone, the bedding being distinct and the rock in many places quite unaltered. The strike is north by west, south by east, with a high dip to the eastwards; that is to say, the strike of these beds is identical with that of the beds forming the foot-hills to the east. Although the identity of the dip

and strike of the Mandalay Hill limestone would point to its belonging to the same sequence of beds as the limestone of the foot-hills to the east, still in view of the altered (crystalline) condition of the rock and the non-discovery yet of any fossils in them, it would seem to be best to leave the question of its age yet open and to say only that the limestone of the Mandalay Hill is probably of the same age as the limestone of the foot-hills.

Previous observations; Dr. Noetling's classification.

Dr. Noetling, Palæontologist to the Geological Survey of India, had gone over this ground along the Mandalay-Lashio cart-road, and the result of his observations was published in the Records, Geological Survey of India, Vol. XXIV, Part 2, page 99. The rocks were classified by him into—

1. Gneissic formation.
2. Submetamorphic formation.
3. Palæozoic group ranging probably from the Cambrian to the upper silurian system.
4. Red sandstones of undetermined age.
5. Tertiary formation.
6. Alluvial formation, probably younger miocene.
7. Volcanic rocks; porphyry of unknown age, granite of gneissic age.[1]

Of these formations, Nos. 1, 2, and 7 do not at all occur along the track gone over by me. Alluvium does occur here and there in the neighbourhood of streams, but I did not stop to map it, as it would have been sheer waste of time to attempt this with the maps we had at our disposal. The ground examined by me included principally the beds grouped above as No. 3 and also portion of No. 4. Whether any of the beds occurring here are tertiary can only be determined by the fossil contents, but no tertiary fossils were found by me.

Dr. Noetling's grouping of the limestones.

In the above paper Dr. Noetling classifies all the limestone beds, commencing from those that form the foot-hills, *i.e.*, the hills forming the westernmost border of the northern Shan plateau, extending to Pyintha and further east across the Shan plateau, into two divisions:—

1. Mandalay limestone without fossils (lower);

[1] Rec., G. S. I., Vol. XXIV, Part 2, page 103.

2. Pyintha limestone with fossils of lower silurian epoch (upper);

and in the lower division is included all the limestone composing the foot-hills, while the beds occurring in the neighbourhood of Pyintha formed the Pyintha beds, the lower division or Mandalay limestone being in this classification characterized by the absence of fossils.

Hills by Tonbo fossiliferous.

I commenced work at Tonbo at the very edge of the hills forming the Shan plateau, and the first fossils here were obtained at ½ to ¾ mile north by west of Tonbo village. In fact all the hills about here, *i.e.*, to the N., N.E. and E. of Tonbo, extending as far as Sedaw village to the east, close to where the Mandalay-Kunlon Railway leaves the plains and begins its first zigzag hilly ascent, were found abundantly fossiliferous, the only drawback being that in many cases the fossils could only be seen in sections, in casts or in fragments, rendering their collection and identification difficult or impossible. Fossils are also met with in great numbers as one goes up the hilly foot-track from Sedaw towards Zibingyi.

Dr. Noetling's grouping of the limestones no longer tenable.

As thus the limestones of the foot-hills, beginning with the very edge of the hills skirting the Mandalay plain, are found to contain fossils, Dr. Noetling's division of "Mandalay limestone without fossils," as applied to these rocks, is no longer tenable. As for the series of "Pyintha limestone:" the fossils of his "Pyintha" beds are not of a character or kind to entitle the beds to the rank of a separate division or series except and until we are in a position to undertake the minute sub-division of the different series of beds, which we certainly are not yet. If they are lower silurian in age, then they but form an insignificant portion of the entire thickness of the beds, namely, from near Tonbo to the neighbourhood of Zibingyi, which belonging as they seem to do to the lower silurian epoch, will thus include the Pyintha beds as part and parcel of them. Thus the divisional name of Pyintha limestone cannot also be retained.

There is another reason why, in view of the fossils found this season in the beds in and about the village of Pyinsa (Pyintha), the name of "Pyintha" limestone could not be appropriately retained, and it is that the Pyinsa village actually stands on beds which occupy a higher horizon (*i.e.*, probably of the upper silurian age) than the Echinosphærites beds which are of the lower silurian

epoch. If the term "Pyintha" has now to be used as a group-name at all, it can now only be properly used to designate the trilobite and graptolite-bearing beds on which the village is actually situated, and not beds at a distance with a different set of fossils.

Why local name of "Tonbo" preferable to "Mandalay".

The name of "Mandalay" might be retained for the group of rocks which I have designated as "Tonbo series," representing the limestones of the foot-hills near Tonbo, Sedaw, etc. But the local name of "Tonbo" seems preferable for several reasons. Besides, by "Mandalay group" Dr. Noetling included all the beds *up to the base* of the Echinosphærites beds occurring between Nyambaw and Pyintha, the Echinosphærites beds being grouped distinct and as "Pyintha" beds. But my Tonbo series *includes* the beds underlying the Echinosphærites beds as well as the *Echinosphærites beds themselves*. So the retention of the name of "Mandalay" as a group-name might introduce confusion. So it seems best to represent the series under the designation of "Tonbo" beds.

From their position in reference to his Pyintha group, the "Mandalay Limestone without fossils" was looked upon by Dr. Noetling as Cambrian (Records, Geological Survey of India, Vol. XXIV, Part 2, page 104). From the fossils collected, however, this season, Dr. Noetling is now of opinion that they are silurian in age.

Nature of the country along the route: Along the railway.

The railway line, as already indicated, passes over the Mandalay plain as far as Tonbo, a distance of ten miles to the south-east from Mandalay. But though the hills commence here, the railway runs for another three miles, *i.e.*, as far as Sedaw, over level ground. At Sedaw it begins its first zigzag ascent of the hills attaining a considerable height at Zibingyi over steep gradients, and from Zibingyi it still goes on ascending until it reaches, at an elevation of over 3,000 feet above the sea-level, the station of Maymyo, the highest point on the Mandalay-Kunlon Ferry line. From Maymyo the line follows a north-east by east course along the edge of a valley as far as Wetwin ("Wenwi" of map), crossing the Kelaung stream there. From Wetwin the route passes over a low level ground—evidently the bottom of a valley, with innumerable streams running to the south-east, until Kyaukkyan is reached, where ascending a slightly higher ground it runs on to the Gokteik gorge. From the eastern side of

the gorge the railway runs over a fairly level ground by Pyounggoung, and crossing the Namsim near its mouth and keeping in the valley runs on along the right side of the river by Thibaw (Hsi Paw) and past it.

Along the cart-road.

While the railway line begins its ascent of the plateau near Sedaw, the cart-road from Mandalay to Lashio *en route* to Kunlon, ascends the table-land about a mile and a half west of Nyaumbaw, that is, at about 4 miles south by west of the Zibingyi Railway Station. A couple of miles east of Nyaumbaw or one mile east of Zibingyi station, there is a sudden rise in the ground, looking like a hill range from the west, running north and south, but really due to the elevation of the ground with a change of dip of the beds to the west. Up to this point (Nyaumbaw), the cart-road had kept a roughly south-east course from Mandalay, but from here it begins to run north-east, keeping all along fairly close to the railway line, and this direction is maintained up to and beyond Thibaw.

Relation of strike of beds with the trend of the hill-ranges.

Among the foot-hills in the neighbourhood of Tonbo, Sedaw, Kwetnepah, etc., it is obvious that the direction of the hill-ranges is coincident with that of the strike of the beds. Further inwards into the plateau, *i.e.*, to the eastwards, the map being of an unreliable character, it becomes difficult to tell how far this agreement holds. By Tonbo and Sedaw the beds strike north by west, south by east, with a high general dip to the east. And although there may be noticed occasional dips to the west, due to folding, it is quite clear that as a general rule the series is ascended as one proceeds from the foot-hills at the western border of it eastwards across the plateau.

It will perhaps be best if the rocks in the different localities were at first separately noted in their proper order as one proceeds from west to east, their relations with one another being indicated later on. Following this plan I will begin with Mandalay itself.

Mandalay Hill.

From the agreement of the dip and strike of the beds of limestone of this hill with those of the limestone of the hills to the east, the Mandalay Hill limestones are evidently of the same system of rocks forming the hills to the east.

Hills near Tonbo.

Tonbo stands at the very border of the foot-hills of the Shan plateau. The hills are composed of a generally thick-bedded limestone, the rock varying in colour from blue to light to dark grey and to bluish grey. That the rock has been subjected to considerable pressure is proved by the presence of innumerable irregular cracks and jointing, often slickensided and by the rock being in places semi-crystalline and brecciated. While the blue limestone, often semi-crystalline, was found here to weather with a black crust, the greyish limestone weathers yellow. North of the village, even at the very foot of the hills, the limestone is clearly seen dipping at 60° to 70°, and even at a higher angle, to the eastwards.

Locality for fossils, north-west of Tonbo.

The first fossils here were obtained at half a mile north by west of the village, at the very edge of the hills, about thirty feet from the level of the fields. From three-fourths of a mile to one mile, on the slopes of the hills facing the plains, north by west of Tonbo village, corals and bivalves, often fragmentary, are abundantly seen on the weathered surfaces of the rock. Foraminifera, corals, sponges, and minute *crinoid* stems are also observable here. Here some big casts of bivalves, which were difficult to identify, were also seen.

Fossils east by north of Tonbo.

Another good locality for fossils in this neighbourhood is about 1½ miles east by north of Tonbo. Fossils are best collected here either on the weathered surfaces of the beds or on the detached weathered fragments strewn about among the beds on the slopes.

Kwetnepah.

This village is situated on the Myitnge river, about four miles south-east of Tonbo. In marching from Tonbo to Kwetnepah, exposures of limestone are met with on the road a mile past Ongyaw. The rock is of the same character as north and north-east of Tonbo and also with a similar dip and strike. Among the fossils found here the coral at least is identical with that found north of Tonbo. That the hill-ranges near Kwetnepah on the Myitnge are a continuation of those of the Tonbo is evident from the identity of strike of the beds and of the hill-ranges in the two places and also that of fossils. The range that is seen south by east of Kwetnepah, on the left bank of the Myitnge, and catches one's eye from its rugged bold outline from a considerable distance, is, there can hardly be any doubt, of the same age as the hills near Tonbo.

The limestones forming the range half a mile east of Kwetnepah are also remarkably fossiliferous. Bivalves, corals, sponges, gastropods, etc., abound; while some distance up the slopes, at a point one mile north-east by east of the village, some beds seemed made up of masses of a coral (Strombodes?). Three or four kinds of corals were noticed on the slopes, one of these at least, a Syringopora, being apparently identical with that found near Tonbo. The rock is light to dark grey and bluish in colour, dipping east by north at 85°.

Fossils.

While in the neighbourhood of Tonbo, Ongyaw and Kwetnepah the hills seemed to be made up of nothing but limestones, varying in colour from light to dark grey and to blue, it is for the first time near Sedaw that one meets with argillaceous shales interbedded with the limestones. About half a mile north-west of the village one can see occurring in the shale harder lenticular patches of a calcareous shale or shaly limestone, these patches often yielding fossils. Strike of the beds here is north-west, south-east. Almost due north of the village, half a mile or so from it, some reddish shales are seen. Among the fossils found here are coral and echimodermatous remains, besides sections of shells.

Sedaw.

Argillaceous shales.

Fossils.

A tributary from the north falls into the main stream at three-quarters of a mile north-east of Sedaw village. The sides of the valley show thick-bedded limestone, but that the centre is occupied principally by shales, though none is to be actually seen, is evidenced by *dèbris* found in the bottom of the valley.

Valley north-east of Sedaw.

One mile due east of the Sedaw village is the little railway station (Sedaw) at the foot of the plateau, and here the railway begins its ascent of the hills. This station is on the thirteenth mile on the line. At the foot the limestone, well exposed in the cuttings, is seen to dip W. 15° S. at 50°; but going up the slopes directly above this point one finds the beds near the top dipping at 35° to E. 10° N., showing that here the limestone beds form a sharp anticline. Looking from this high point northwards, one notices an exposure of a very red coloured rock towards the head of the valley of the tributary stream which falls into the

First ascent of railway up the hills.

Over an anticline.

Sedaw river three-quarters of a mile north-east of Sedaw. There is little doubt that this red rock is a portion of the synclinal fold of the red shale which is well exposed on the railway about the 17th mile (see Plate, Fig. 1). The railway on leaving the Sedaw station goes up in a very zigzag line as it first ascends, and follows a general south-east course for some distance, then turns north-east and shortly reaches the third and fourth reversing points between the seventeenth and eighteenth mileposts. Here is exposed a thickish mass of bright red calcareous shale, dipping E. 10° N. at 50° to 55°. The red shale is highly calcareous, much pressed and indurated and often exhibits a shining lustre along the lamination planes. Occasional minute stems of crinoids are all that could be obtained from these beds in the shape of fossils.

Red shales by the 17th mile.

It is noticeable that if one comes up from the foot of the hills along the new railway cuttings one does not come across or see a single indication of a fossil, however closely one might examine the fresh faces of the rock exposed in the cuttings, leading one to suppose that these beds must be perfectly devoid of organic remains. But let one follow the old foot-track that ascends the same hill to the north of the railway line—the old footpath leading from Sedaw to Zibingyi—and one is agreeably surprised at the quantities of fossils one meets with on the very foot-track on the weathered surfaces of the rock. *Euomphalus* is specially abundant, with *Orthoceras*, *Gomphoceras* (?), etc., etc.

Fossils.

The red shales just above referred to, pass eastwards, *i.e.*, upwards, into mud-coloured argillaceous shale. This argillaceous shale is in places blackish and exceedingly hard, as seen by the 18th mile. From this point the Zibingyi railway station lies about two miles east by north in a direct line, but the actual length of the railway between these points is four miles. Proceeding towards Zibingyi from the eighteenth milepost various kinds of limestone are passed over, all dipping eastwards and rather at a high angle. Occasionally a bed or two of limestone, perfectly black in colour, is met with which might be taken for coal from a distance. About midway between the 18th mile and the Zibingyi station argillaceous shales are seen, these often being reddish in colour and with concretionary

The beds as traced towards Zibingyi.

masses of limestone, grey or flesh-coloured, and fossils such as *crinoids*, *Orthoceras*, etc., have been found in them. Nearer Zibingyi, these red shales and clays with calcareous concretions are succeeded by limestone beds which on approaching Zibingyi assume a low dip.

Zibingyi syncline.

About 1¼ miles west of Zibingyi station, fragments of trilobites are met with together with conical little bodies beautifully sculptured transversely, which are most probably Styliolas. Next after passing over some limestone and argillaceous shales were found monoprionidian graptolites, with some minute bivalves, etc. For a mile west of the station hardly any exposures of rocks are visible; but proceeding east along the line and past the station, some thin-bedded limestones and soft yellow shales are met with one mile east of the station. These dip, however, to the west and contain trilobites and graptolites, together with the Styliolas and bivalves. Thus there is a little syncline here with Zibingyi station as its centre.

By the cart-road from Tonbo.

If one proceeded by the cart-road from Tonbo, which is on the thirteenth milepost on the Mandalay-Lashio cart-road, he would meet with thick-bedded limestones with corals, etc., up to a point 1½ to 1¼ miles north-east of Kwetnepah. A little beyond this point is the seventeenth milepost (on the cart-road), and beyond this is an exposure of a red calcareous shale, which is evidently an outcrop of the same rock as is exposed about the 17th mile on the railway. From here the road keeps a zigzag south-east course for some distance, often showing the same red and grey argillaceous shales, with limestone beds much disturbed and folded. The cart-road ascends the plateau in a zigzag manner 1¼ to 1¾ miles west of Nyaumbaw. A little over a mile west of the Nyaumbaw Inspection Bungalow, which is on the twenty-third milepost on the cart-road, or to be precise, between the fifth and sixth furlong posts past the 21st mile, I found, in a light grey limestone with argillaceous shale, some fine specimens of the stems and arms of a large crinoid, with Orthoceras, etc. The rock about here is a grey thinnish-bedded limestone with calcareous and argillaceous shales, the shaly limestone being sometimes of a flesh colour. By the police station and the Priests'

Red shales.

Nyaumbaw.

Specimens of a large crinoid.

House at Nyaumbaw a limestone which unweathered looks not unlike a gneiss, is associated with reddish shales with calcareous concretions and yields abundance of rather small crinoid stems and Orthoceras. Between the twenty-fifth and twenty-sixth mileposts, that is, about two miles east of Nyaumbaw, and at the foot of the rising ground, the rocks are also well exposed, being a red shale with calcareous concretions interbedded with thin-bedded limestone, and in these shales were found *Echinosphærites, Orthoceras*, crinoid stems, etc., and with these, also some other fossils rather of large size, some measuring four to five inches across, occur. But what they may be it has not been possible to determine yet.

Locality of Echinosphærites.

The rise in the ground here corresponds to a change in the dip, that is to the western direction, of the beds, this line of elevation being the continuation of the high ground also seen one mile east of the Zibingyi station.

Proceeding up this steepish rise along the cart-road, the level ground is reached ½ to ¾ mile west of Pyinsa (or Pyintha) (between the twenty-seventh and twenty-eighth mileposts) and here the beds are seen resuming their dip again to the east. A short distance before Pyinsa is reached, soft yellowish shales with trilobites and Styliolas are met with dipping east. A little to the south-east of the village is exposed, on a stream-bed, a dark grey to blackish limestone with graptolites. Coming back again to the cart-road and going north one comes upon, at a point between the first and second furlong posts past the 29th mile, that is, about 1¼ miles short of the Thongdaung Inspection Bungalow, and in the very middle of the road, some thin-bedded black limestone which has only to be turned up to show the graptolites they contain, being evidently an outcrop of the same beds as are seen on the stream-bed south-east of Pyinsa. From here hardly any exposures are seen till the sixth furlong post after the thirty-first milepost is reached, when some yellow shaly clay containing trilobites and Styliolas are met with. Beyond the village of Chingenah (on the 32nd mile) mud-coloured argillaceous shales interbedded with limestone bands are seen, dipping east at 20° and evidently overlying the series of beds containing trilobites and Styliolas just seen to the south. As from this point beds higher in the sequence are met with as one proceeds

Pyinsa and neighbourhood.

Zibingyi beds.

along the cart-road towards Maymyo, we might deviate here a little from the cart-track and inquire if the trilobite and graptolite bearing beds of Zibingyi are to be seen along the railway line east of Zibingyi. They do appear on the line about one-third mile north of Thongdaung station and are traceable to a point a little distance south of Waboye village. The beds here have yielded *trilobites*, *graptolites*, and Styliolas with a fair sprinkling of bivalves, etc. Thus the trilobite and graptolite beds which form a small syncline about Zibingyi occupy also two other areas in the neighbourhood, namely, one about the Pyinsa (Pyintha) and Thongdaung villages and the other between the Thongdaung Railway Station and the Waboye village. As I was directed to march rapidly through this part of the country, I made no attempt to trace the boundaries of these areas.

Another area of Zibingyi beds.

As one proceeds north-eastwards either along the railway from near the village and Waboye, or along the cart-road from near Chimgenah, one meets with beds higher and higher in the series.

Before noticing these higher beds, a word more might be said in reference to the Sedaw-Zibingyi section. We found a mass of red calcareous shales by the 17th mile on the railway, these being also exposed between the seventeenth and eighteenth mileposts on the cart-road. We also found certain red shales with calcareous beds well exposed between the twenty-fifth and twenty-sixth mileposts on the cart-road (about two miles east of Nyaumbaw), these coming in below the Zibingyi trilobite and graptolite-bearing beds and yielding Echinosphærites, etc. It seems to me that the first-named red shales are lower in the series than the Echinosphærites-bearing beds. For, in the first place, in physical characters they present great differences; for while the red shales by the 17th mile on the railway are highly calcareous, much pressed, and indurated, presenting a shiny lustre on the lamination planes and free from any calcareous concretionary masses in them, those on the cart-road, well seen between the 25th and 26th mileposts are, on the contrary, not calcareous (at any rate nothing like what the others are), do not exhibit the signs of the great pressure and crushing, such as induration and production of shiny lustre along lamination planes that the others show and have abundance of concretionary masses of limestone associated with them. In short,

Red calcareous shales of seventeenth milepost on the Railway and the Echinosphærites-bearing beds.

physically, the one looks quite different from the other. As for organic contents, while only minute *crinoid* stems were all that could be had from the one, abundance of remains of Echinosphærites and other fossils occur in the other.

Tonbo-Sedaw section: its age, etc.

With reference to the structure and age of the Tonbo-Sedaw section, the beds are nearly vertical, the general strike being north by west, south by east. It is also very probable that there has been some repetition of the beds through folding here. That the limestones in the neighbourhood of Tonbo are the same as those near Kwetnepah appears certain from the strike of the beds and also from similarity of fossils. Of the foraminifera, corals, sponges, crinoids, bivalves, gastropods, and cephalopods that have been found here, the greater part have not yet been determined. As the Tonbo-Sedaw section is meant to include all the beds below the Zibingyi syncline, the shaly limestone containing the rather fine specimens of the arms and stems of a large crinoid found on the cart-road between the twenty-first and twenty-second mileposts (that is, one mile west of Nyaumbaw), as well as the *Echinosphærites*-bearing red shales with calcareous concretions, come in in the upper part of the Tonbo-Sedaw section. From among the fossils found in the beds bordering the plain just north of Tonbo, Dr. Noetling identifies a coral as of the silurian age. Hence these beds composing the foot-hills near Tonbo are silurian, that is lower silurian, in age.

Zibingyi beds: their age.

Zibingyi section.—As only monoprionidian graptolites have been found in these beds and no diprionidian ones, this would seem to indicate an upper silurian age for the Zibingyi beds.

Along the cart-road.

Waboye-Maymyo Section.—After passing over the trilobite-bearing shales last seen on the cart-road a little short of the thirty-second milepost, one comes upon, in going northwards towards Maymyo, limestones with shales between the thirty-second and thirty-third mileposts. Exposures then become scarce, only bits of limestone being occasionally visible. A little past the 39th mile the road passes through a low range which shows a light grey sandstone, hard, compact, and moderately fine-grained at the foot of the hill, but getting finer-grained and quartzitic towards the top, the dip being east-30°-north at 20°. This is the first sandstone one comes across after leaving Tonbo. After a

short blank another range is crossed by the cart-road at between the fortieth and forty-first mileposts, where the rock from being a white, soft, friable, flaggy sandstone, rather coarse-grained, passes up into a bluish, hard grey, compact, thick-bedded, calcareous sandstone or siliceous limestone, in places quite brecciated. Of such rocks are made up the hills one mile west of Maymyo. The dip is here 25°—30° to east-15°-south.

Along the railway.

The same section is better exposed on the railway track from Wayboye to Maymyo, the principal rock seen being a sandy limestone or calcareous sandstone with occasional intercalations of shales, all dipping eastwards. No fossils except a few minute gastropods were extracted from these beds.

The section an ascending one.

That the section is an ascending one, the dip of the beds as they are followed from Thongdaung Railway Station towards Maymyo, would clearly indicate. But if that were not quite convincing, the fact of the introduction of a new, *i.e.*, sandy, element in the hitherto perfectly purely calcareous rocks, giving a new character to the beds in this section, ought to remove all doubt. For nowhere in the Tonbo-Sedaw section does one ever meet with anything but perfectly purely calcareous beds, free from any admixture whatever of any sandy element. If the Waboye-Maymyo beds were older than the Zybingyi trilobite-bearing beds, then we should hardly expect that, while the Waboye-Maymyo beds were deposited in shallow and non-clear waters, there should not be even a trace of such impurities whatever, in the beds underlying the Zibingyi series anywhere else and in beds evidently laid down in such close proximity.

Maymyo.

Maymyo is situated on a piece of level ground surrounded on all sides by hills. On the west and south-west the hills show sandstone and siliceous limestone, dipping east by south at about 25°. North westwards the exposures are few, limestone being occasionally visible. But the hills to the south are even more disappointing, for in that direction it is difficult to come upon a piece of solid rock, a thick mass of soil overspreading the ground everywhere. Towards the north, however, *i.e.*, on the footpath leading to Naungkangyi as well as that to Tonbo, and at a point about two miles north of Maymyo, yellowish shaly clays and sandy shales are exposed and they are found to be fairly fossiliferous

Crinoid stems, Orthoceras, fragments of trilobites, Orthis, Strophomena, Rhynchonella, etc., are derived from here, though often much distorted, owing to the great crushing to which the beds have evidently been subjected. Some of the shales are somewhat white and chalky, while others are ferruginous.

Maymyo to Wetwin ("Wenwi" of map).

Maymyo is on the 42nd milepost on the cart-road to Lashio on the way to the Kunlon Ferry, while Wetwin ("Wenwi" of map) is on the 55th. In proceeding from Maymyo to Wetwin by the cart-road exposures are few, but the rock chiefly seen is the calcareous sandstone or siliceous limestone. If one goes along the railway track, beds of a greyish limestone with a distinct dip to the east are visible on the stream-bed about one mile east of Maymyo. Beyond this point, although the cuttings show the sandy limestone all along the line to Wetwin, they are found so pressed and crushed and broken that it is often difficult, if not impossible, to even make out the dip, and this state of things continues all the way to Wetwin. With the exception of a very few minute gastropods found about half-way between Maymyo and Wetwin, no other fossils were obtained from here.

Fossils.

Just north of the village of Wetwin, *i.e.*, by the 55th mile on the cart-road, the western bank of the road exposed, on being cut into a grey to yellowish toughish shale, and from this a fair collection of fossils was made, among the fossils being Pterygotus, Fenestella, bivalves, etc.

Wetwin to Kyaukkyan.

The cart-road on leaving Wetwin runs at first north by east and then a north-east course is maintained till it reaches Kyaukkyan on the 74th milepost. This interval from Wetwin to Kyaukkyan is almost a perfect blank, because of the ground being here low and level and nothing whatever being seen except bits of limestone here and there. A good deal of alluvium overspreads the country. Even the hills, as between Sikho and Thonze, present no exposure of rocks owing to the thick soil. After passing over this blank of nearly eighteen miles, it is a great relief and satisfaction to come across, at Kyaukkyan, shales which yielded plenty of fossils. A low range occurs here, running north by west and south by east, and the railway passes through a deep cutting through this range. It is a fairly long cutting, and at the western end of it is

Fossils of Kyaukkyan.

exposed a shale dipping eastwards; in the centre occurs a thick-bedded, highly crushed and brecciated siliceous limestone; while at the very eastern extremity, after a blank of 200 feet or so just beyond the central mass of grey limestone, is seen a darker grey limestone with a distinct dip to the west. Fig. 7 represents what is actually to be seen in the section along this cutting, while as to how I would read this section is represented in Fig. 8 (see Plate, Figs. 7 and 8.)

Section at Kyaukkyan.

I thus make out a synclinal fold here. The easterly dip of the shales is unmistakable, and it seems also clear to me that the central limestone mass shows at its western portion a distinct bedding parallel to, and identical with, that of the shales. The rest of the central mass of limestone looks so confused and crushed that all signs of the original bedding has disappeared, except perhaps at its very eastern border, where I think one can just make out a bed as dipping to the west. The westerly dip of the limestone in the eastern end of the cutting (*i e.*, through the darker-grey limestone) is perfectly clear. Thus it appears to me that the limestone in the eastern end of the cutting passes under, and is thus older than, the fossiliferous shales at the western extremity of the cutting.

These fossiliferous shales are of course well exposed in the railway cutting, but they are also to be seen on the cart-road which passes close along the railway here.

Kayaukkyan to Nawnghkio and the gorge.

From Kyaukkyan the railway line as well as the cart-road run north-east by east as far as Nawnghkio, five miles from Kyaukkyan, the limestone being observed on the route to dip at a small angle to the west. From Nawnghkio the railway proceeds towards the Gokteik gorge, in an east by north direction, while the cart-road runs nearly north, crossing the gorge at a point about 2 miles (in a direct line) north-east of the town. In the neighbourhood of Nawnghkio no good sections are available, but the beds must resume their easterly dip about here, for on the western side of the gorge close by the beds are seen dipping to the east.

As one follows the railway track from Nawnghkio to the gorge the prevailing rock is found to be the light grey, siliceous limestone with occasional calcareous blue beds and some sandy shaly beds; the dip being east by south. The western slopes of the gorge at the

point where they are making the railway bridge are a good deal covered with soil and calcareous tufa and no good sections are visible, but on the opposite, eastern bank, thick-bedded, siliceous limestones are well exposed, forming precipitous cliffs.

The section across the gorge at the point where they are making the railway would roughly be like what is represented in the sketch section shown in Fig. 6 (see Plate), where the rocks seen on the eastern side of the gorge are, in descending order:—

1. White calcareous sandstone, or sandy limestone (as at Yebin).
2. Sandy shale, greenish white, thin bedded, soft, weathering black, with a masonry look on the weathered surface, in places brecciated.
3. Fine-grained argillaceous shales (somewhat sandy) breaking up into small angular pieces.
4. Blank.
5. Fine-grained, white calcareous sandstone.
6. Massive bedded white to light to dark-grey siliceous limestone.

In Fig. 6, R. stands for part of the railway bridge as seen already constructed at the time of visit to the gorge, and N6 stands for the "natural" bridge, composed of calcareous tufa.

"Natural" bridges over the gorge.

There is a "natural" bridge here (one of several in this neighbourhood) over which they are taking the Railway bridge. These "natural" bridges have been formed by calcareous tufa, *i.e.*, from the re-deposition of calcium carbonate from waters containing the mineral in solution.

Section in the gorge along the cart-road.

If one proceeded, however, to cross the gorge by the cart-road from Nawnghkio, the section would appear to be somewhat different from that observed near the Railway bridge. As he descends into the gorge, he will pass over, on the western side, siliceous limestones with purer calcareous beds, light to dark grey and bluish in colour; greenish, rather hard, sandy shales, in places micaceous; sandy clays, and red shales much indurated; while on the eastern or Chaungzon side will be noticed limestones, arenaceous shales, and siliceous or sandy limestones. From the greenish sandy shales, between the 84th and 86th mileposts, on the western side of the cart-road bridge, fossils similar to those found two miles north of Maymyo were collected. On the eastern side of the gorge, at the 88½ mile (a mile and a half past the Chaungzon Inspection Bungalow), or about one mile north by west in a direct line from the

cart-road bridge over the gorge, a few fossils were also obtained from a somewhat arenaceous shale. The difference in the character of the two sections—one along the cart-road and the other by the Railway bridge—is due to the fact that, while in the northern (cart-road) section across the gorge older beds are exposed in the deeper parts of the gorge, only the higher (younger) beds are to be seen along the railway track.

Thick surface soil east of the gorge.

On the eastern side of the gorge a new difficulty presents itself. Hitherto the vegetation and soil had been a drawback bad enough; but now the surface red soil, resulting from the decomposition of the rocks *in situ*, assumes such thickness and proportions and is so widespread as to baffle all attempts at getting at the solid rocks underneath. The railway cuttings near the gorge, which are in places of considerable depth, show the most irregular and curious way in which the rock (limestone) has been eaten into in the course of its decomposition from above. And this state of things prevails over a considerable distance as one proceeds north-eastwards from the gorge towards Pyoung-goung and Thibaw.

Fossiliferous shales two miles north of Gokteik village.

A mile and a half beyond the Gokteik Inspection Bungalow, that is, about 100 yards short of the 97th milepost on the cart-road, or two miles north of the Gokteik village, was discovered, on the eastern side of the cart-road, *i.e.*, between the cart-road and the railway track, which are only a few yards apart here, at the bottom of an excavation from which the soil had been extracted for making the railway road, a very fine-grained, well laminated, purely argillaceous shale, grey to bluish in colour, but occasionally carbonaceous, and splitting up well along lamination. A rather interesting group of fossils was obtained from these beds. A short distance south-east of this spot and on the eastern side of the railway line are exposed, at the foot of a hill, some white sandy limestones; these also yielded a few minute bivalves and gastropods. These two collections constitute all the fossils that could be got in the neighbourhood of Gokteik village.

Wetwin and Gokteik shales not identical.

Although physically the Wetwin shale somewhat resembles the Gokteik shale just described above, the fossil contents show that they are not the outcrops of the same beds and that the one is different from the other, the former being of an older age than the latter.

On the way to Pyoung-goung, with the exception of a few minute gastropods derived from some limestone near Tengwing, between the 99th and 100th mile-posts, where the beds are seen dipping at a small angle to E.25°N., nothing whatever was obtained in the way of fossils, most of the exposures being bits of limestone at the bottom of quarries dug in connection with the railway making. The hills on either side were here and there explored, but the thick soil on them defied all attempts to get at the rocks beneath.

On the way to Pyoung-goung.

Among the hills to the east and north-east of Pyoung-goung there are some outcrops of thick-bedded limestone dipping east by north at 10° to 15°. They yielded however no fossils.

Pyoung-goung to Lwekaw.

From Pyoung-goung (on the 105th mile on the cart-road) to Lwekaw (on the 116th mile) hardly any exposures are visible along the cart-road, but sections are available along the railway line. Proceeding, then, by the latter: From some limestone exposed in the railway quarries on the eastern side of the line, just south of Loiyang, a village one mile north of Pyoung-goung, some minute gastropods and sections of fossils, not recognizable, were obtained. Numerous cuttings, principally through siliceous limestones, occur along the line, all exhibiting signs of much crushing, but yielding no fossils. But at a point four miles from Pyoung-goung there is an exposure of a soft yellow shale which yielded numerous Fenestellas, Crinoid stems, a trilobite, some corals, and bivalves. This is succeeded by a blank for three miles, when again, that is, about three miles west of Lwekaw, a good section of limestone is obtained. The rock here is rather thin bedded mostly and grey in colour, some of the beds being, however, bluish. From these were extracted some ferns and bivalves. The dip here is east by north at 25°. From here to Lwekaw the section is nearly a blank, except some beds of limestone seen on the stream-bed at Lwekaw itself.

Fossils near Loiyang.

Fossils four miles north-east of Pyoung-goung.

Exposure three miles west of Lwekaw.

Lwekaw to Kyinsi.

From Lwekaw to Kyinsi (on the 125th mile), a distance of 9½ miles by the cart-road, exposures of limestone are occasionally met with along the cart-road, but though no success resulted so far as the finding of any fossils

went, that does not of course prove that these beds are not fossiliferous. The railway track, however, gave better results. The section is a blank for some miles from Lwekaw. At a point about three miles west of Kyinsi, which is situated near the mouth of the Namsim river, a fine section of argillaceous shales with limestone is exposed, but this yielded no fossils. Nearer Kyinsi, however, there are several small cuttings between 1 and 1½ miles from Kyinsi. Argillaceous grey and reddish calcareous shales with grey and blue limestones exposed here are very fossiliferous. The dip here is north-east at 45°. These fossils being similar to those of the Kyaukkyan beds, we have at Kyaukkyan and at Kyinsi outcrops of the same beds. Going on towards Kyinsi, the exposure by the cart-road bridge on the Namsim, a little above its mouth, yielded some plant-remains and corals.

Fossils at between 1 and 1½ miles west of Kyinsi.

These fossils identical with the Kyaukkyan ones.

From Kyinsi (125th mile) to Thibaw (Hsi Paw), which is on the 132nd milepost on the cart-road to Lashio, no solid rocks are visible whether one proceeds by the railway or the cart-road. There is a saline spring at Bawgyo, from which the Burmans extract, by simple evaporation, a lot of salt for purposes of sale.

Kyinsi to Thibaw.

Thibaw itself is in a valley and gives no sections either in the town or in its immediate vicinity. The ¼-inch map, which was the only map I had with me of this neighbourhood, is also far from satisfactory, so far as the hills in the immediate neighbourhood of the town are concerned, adding thus to the difficulties of one's work. Going on to the hills to the north-west and north of the town, one finds, by the village of Honam (not on the map, but near "Babaiki" of map) exposures of limestone, which is here a pure rock, quite free from any admixture of sand, passing, traced eastwards, into an argillaceous shale, finely laminated, pale yellowish green in colour, and somewhat calcareous at first, but gradually being free from the calcareous element and giving place to a grey and greenish, purely argillaceous, shale. The limestone above the village yielded sections of bivalves, not, however, recognizable; but in the small exposures available of the shales into which the limestone is seen to pass, I did not succeed in finding any fossils. The shales are here vertical.

Neighbourhood of Thibaw (Hsi Paw).

striking nearly north and south. On the hills north-east of this point shales are clearly visible at places. Going on again to the hills north by east of Thibaw, bits of a sandy limestone are at first passed over as if the parent rock *in situ* below were a calcareous sandstone or arenaceous limestone. Proceeding further in the same direction fragments of sandstone are seen. After a blank, a conglomerate, composed of fragments of limestone and of sandstone, is met with. The pebbles are of different dimensions, some measuring as much as 6 inches in length. Some of the constituents are well rounded, but a good many exhibit an angular outline. Proceeding further, no regular beds were seen, but fragments of sandstone were noticed on the ground. A spotted variety of the sandstone was noticeable as being very abundant—the rock being a light grey sandstone with evenly distributed fine dots of red. Beyond this point the ground became obscure.

Thibaw to Kongsa.

Crossing over to the southern bank of the river at Thibaw and proceeding along the cart-road eastwards, within half a mile of the Thibaw Inspection Bungalow (at $133\frac{3}{4}$th mile) the ground rises by the left bank of the river, but no solid rocks are exposed until about quarter to half a mile further beyond, where a sandstone is seen. It is a hard rock, medium to coarsish-grained, yellow to brownish green, and much jointed; but as one goes on a reddish or reddish-purple variety of the rock, interbedded with thin bands of purplish shales, and in one place an impure thin calcareous band, are noticeable. The rock is, however, beautifully exposed a little further on, that is, in the railway cutting on the right bank of the river, at a point two miles due east of Thibaw. It is a reddish purple, rather fine-grained sandstone, thin to thickish bedded, with intercalated shales of the same colour, dipping E. 35° S. at 55°. In going on, by the cart-road, to Kongsa, about nine miles east of Thibaw, the reddish-purple sandstone and shale constitute the chief rocks seen, but about one mile west of the Kongsa Bungalow, a very impure limestone, evidently interbedded with the sandstone and shales, is seen.

Sandstone and shales, with impure calcareous beds.

Near Thibaw limestone seems to pass into shales and sandstone.

Thus from the examination of the ground in the neighbourhood of Thibaw it seems to me that the limestones pass into argillaceous shales, which become gradually sandy and eventually pass into the

red and purple sandstones east of Thibaw. The conglomeratic band seen three miles north by east of Thibaw apparently marks only local denudation. As I had to resume my return march to Mandalay from Kongsa, my examination of the ground did not extend beyond this point.

Having now cursorily glanced over the character of the different rock-exposures one meets with as one passes along the Mandalay-Lashio cart-road or railway track from Mandalay to Thibaw, and pointed out the various localities which have yielded fossils during the season, it now becomes necessary to indicate the general structure of the ground, showing the relations of the different groups of rocks with one another and their probable age.

Rocks classified.

The rocks passed over from Tonbo on one's way to Thibaw may be arranged into the following divisions :—

(1) Tonbo beds.
(2) Zibingyi beds.
(3) Maymyo beds.
(4) Wetwin beds.
(5) Kyaukkyan beds.
(6) Gokteik beds.
(7) Thibaw beds.

Tonbo Series.

By Tonbo beds I shall indicate the sequence of the limestone beds forming the foot-hills of the Shan plateau, *i.e.*, the hills in the neighbourhood of Tonbo and Sedaw. The rock is purely a limestone in the neighbourhood of Tonbo and it is only by Sedaw that argillaceous shales begin to appear. The limestone passes gradually into shales which, from an ordinary grey or mud-coloured variety, passes into a red kind. The north-and-south valley, a little to the north-east of Sedaw, evidently resulted from the excavation of the red shales, etc., that form a syncline here, the syncline being followed eastward by an anticline whose eastern limb is now exposed about the 17th milepost, that is, the third and fourth reversing points on the railway and also between 17th and 18th mileposts on the cart-road. These red shales pass up into dark grey shales and these into limestone. In this series may thus be included all the beds as far as the base of the Zibingyi syncline. The beds near Nyaumbaw with the Crinoids, *Orthoceras*, *Echinosphærites*, etc., will thus come in in this series.

The fossils found in the Tonbo beds are corals (*Syringophora*, Strombodes?), brachiopods, lamellibranchs, gastropods (*Euomphalus*), stems and arms of Crinoids, *Echinosphærites*, *Orthoceras*, *Gomphoceras?*, etc. These have not been specifically determined yet, but they point to a lower silurian age.

Zibingyi Series.

Under the designation of Zibingyi series are included the limestones and shales forming the synclinal fold at Zibingyi It does not seem to me of much use or profit yet to attempt to subdivide these beds into more than two divisions, namely, an upper one, containing graptolites, and a lower one with the trilobites and Styliolas. Orthoceras and Crinoid remains occur everywhere, abounding as they do also in the Tonbo beds, and so they are not of much help in a minuter classification of any of the beds here.

The Zibingyi series of beds occur in three little separate areas: one at Zibingyi itself, the second about Pyinsa and Thongdaung, and the third just north of the Thongdaung Railway Station.

The specimens of graptolites that have been collected from these localities are all of the monoprionidian order, not a single diprionidian graptolite having been found in them. Hence the presumption is that the Zibingyi series of beds are, to judge by the graptolites alone, of the upper silurian age.

Maymyo Series.

The Zibingyi beds pass up into shales and limestones with introduction of sandy elements among them. Sometimes the rock is an arenaceous limestone or calcareous sandstone; at other times it is a pure sandstone; these varieties being well seen as one passes from near Waboye to Maymyo. The hills just west of Maymyo are composed of this siliceous limestone and calcareous sandstone. About two miles north of Maymyo argillaceous shales, somewhat sandy, are exposed, and Orthis, Strophomena, Fenestella, fragments of trilobites, etc., have been found in them. Apparently the siliceous limestones, etc, seen west of Maymyo pass up into these shales and as the fossils indicate a silurian age, the Maymyo series of beds seem to belong to the upper silurian period.

The beds exposed in the deeper parts of the Gokteik gorge, as seen by the cart-road bridge, are silurian in age. But no characteristic fossils having yet been found in those exposed in the upper parts of the gorge, as seen by the Railway bridge, it is difficult to say if they are devonian or carboniferous.

The name of Wetwin (" Wenwi " of map) series may be applied to the group of rocks in the neighbourhood of Wetwin, a fairly good collection of fossils having been yielded by them. The fossils were found in a band of toughish shale interbedded in the siliceous limestones. A band of ironstone occurs a little below the fossiliferous shales. Among the organic remains found here occur Fenestella, Hyolites?, lamellibranchs, Entomis serrato-striata?, and Pterygotus, which would seem to point to a devonian age.

Wetwin Series.

If the Wetwin beds are devonian, it is not likely that the shales seen 2 miles north of Maymyo on the way to Naungkangyi are other than upper silurian. For if they were lower silurian, faulted up against the upper silurian siliceous limestones of the hills just west of Maymyo, it is difficult to explain the total and entire absence of the upper silurian Zibingyi beds between Maymyo and Wetwin.

There is a blank of 18 miles between Wetwin and Kyaukkyan in which only an occasional outcrop of limestone is seen. At Kyaukkyan, however, the shales at the western end of the railway cutting are highly fossiliferous. This series of beds—the shales with the associated limestones—at Kyaukkyan, may be termed the Kyaukkyan series.

Kyaukkyan Series.

By the 97th mile post on the cart-road, or 2 miles north of Gokteik village, occurs a dark grey toughish shale which has yielded some rather interesting fossils. These shales with their associated beds I will designate as the Gokteik series.

Gokteik Series.

The limestones as seen in the hills north of Thibaw, pass into argillaceous shales and these apparently into the reddish-purple sandstones so well exposed on the railway cutting 2 miles east of Thibaw. No fossils have been found in them, but from their position they are younger than the Kyinsi beds. These shales and red sandstones with limestone constitute the Thibaw beds.

Thibaw Series.

Now the Kyaukkyan fossils appear again between 123rd and 124th mileposts, near Kyinsi, and in the interval between these points, in two localities, namely, one at 2 miles north of Gokteik village and the other at 4 miles north-east of Pyoung-goung, fossils were discovered. As there are considerable gaps between these several points of fossiliferous exposures, the structure of the ground must be mainly dependant on, and inferred from, the nature of these fossils.

From the occurrence of a synclinal fold at Kyaukkyan, as I make it out to be, and the repetition of the Kyaukkyan beds at Kyinsi, the structure of the ground would appear to be simple, *i.e.*, a syncline followed by an anticline, as attempted to be diagrammatically represented by Figure 9 (See Plate, Figure 9) which, if true, would make the Gokteik and Pyoung-goung fossiliferous beds older than the Kyaukkyan (or Kyinsi) beds. All the fossils have not yet been specifically determined, but I understand that the Kyaukkyan fossils are regarded as devonian. As regards the Pyoung-goung fossils, there is, I believe, nothing in them to prevent their being regarded as devonian or perhaps even silurian. But this does not seem to me to be the case with the Gokteik fossils. I have not been able to identify them yet, but will try to indicate some of the characters of the most important ones here, all of these belonging to the Arthropoda. Fossil No. (1). This presents an outline broader in the cephalic end and tapering towards the tail, with the limbs, all of them apparently situated near the cephalic end, well segmented and with the minute hairs on them distinctly visible; and there is no indication of segmented limbs with hairs towards the tail, which looks flattened and fan-shaped. There is no sign of trilobation whatever in any of the specimens of this fossil, and no haired limbs at the tail end. All this would seem to me to point against its being a trilobite. The resemblance of the organism, however, to a macrurous decapod appears to me to be close. Fossil No. (2). That this also belongs to the Crustacea there seems to be no doubt. With its body slightly bent and tapering towards the tail, and with its dorsal segmented chitinous or horny-looking carapace, and segmented ventral limbs, the resemblance is so close and striking to some of the macrurous decapods that I can scarcely entertain any doubt in my mind as to its being one of them. Fossil No. (3). In this only a portion of the posterior terminal or tail end of the animal is preserved. I do not feel quite sure about it, but the resemblance leads me to regard it as belonging to Eryon, also a macrurous decapod, or to a crustacean closely allied to it. Fossil No. (4). The outline of the organism is oval, the cephalic portion presenting a conical section, with segmented slender limbs about the shoulders and about the region corresponding to the pelvis. In

Structure of the ground.

Characters of some of the fossils of the Gokteik Series.

some of the limbs the hairs can be well made out. Everything considered, it looks like the remains of an insect of the Hemiptera or Coleoptera order. Besides these, other specimens, collected also from here, appear to be fragments and portions of wings and other portions of insects.

Inference from these fossils.

Now Hemipterous insects appear in the silurian period and range up to the present day, while Coleopterous insects do not appear till the trias. So, as far as the insect remains here are concerned, they do not help us much in determining the age of the Gokteik beds. But should the other Crustacean fossils really prove to be the remains of macrurous decapods, as they appear to me to be, then, since no typical decapods appear until the trias is reached, the Gokteik beds cannot be older than trias and must be triassic or younger. Should the Gokteik beds be then mesozoic, they must be supposed to have been faulted in against and between the devonians at Kyaukkyan and Kyinsi, should the beds at Kyaukkyan or Kyinsi be devonian.

Should the above be the correct interpretation of the structure of the ground, then the Thibaw beds (the limestones, shales and the reddish-purple sandstones [1]), being higher in the sequence than the Kyinsi beds, must be looked upon as upper palæozoic.

Another view as to the age of the beds.

The fossils collected this season have not yet been examined closely or determined specifically, and until this is done the above explanation as to the structure of the ground must be regarded as provisional. Such being the case, it may perhaps be permissible to indicate here any other view or views that may have been entertained as to the possible age of the beds and structure of the country traversed this season. As already indicated, I took it that there was a sharp syncline at Kyaukkyan, followed by an anticline, the eastern limb of which was now exposed at Kyinsi; and that all the beds—the Gokteik series—between these points, lying under this anticlinal fold, were thus older than the Kyaukkyan or Kyinsi beds. Should the Gokteik beds be triassic or younger, the Kyaukkyan beds would necessarily be younger still, that is, middle or upper mesozoic; [2] and in that case the shales and red sandstones of the

[1] These are the red sandstones of undetermined age of Dr. Noetling. Rec. G. S. I., Vol. XXIV, pt. 2, pp. 103 and 104.

[2] I may add here that in the Kyaukkyan collection there are some fossils which are so remarkably like some mesozoic ones that should they prove to be what they look like, they would carry the age of these beds into the upper mesozoic, namely, cretaceous, period.

neighbourhood of Thibaw, being younger than the Kyinsi beds, would be cretaceous or even tertiary. I might state here that the conglomerate and red sandstone I have described as occurring near Thibaw present such close resemblance to the same rocks found by Mr. Middlemiss this season in the southern Shan States, not very far from our own ground, that in all probability whatever the age of the one is also the age of the other, and I believe Mr. Middlemiss is inclined to look upon them as of tertiary age.

Economic Geology—Among the economic products come across during the field season just ended may be mentioned :—

(1) Metallic ores.
(2) Limestones.

(*1*) *Metallic Ores.*—Ferruginous ore is the only metallic ore I met with in my traverse from Mandalay to Thibaw. The localities where I saw this are—

(i) Between the third and fourth furlong posts past the 39th mile on the Mandalay-Lashio cart-road, or 2½ miles beyond the village of Singaung, or about three miles south-west of Maymyo a highly ferruginous rock is seen along the roadside. It looks rich in iron. The rock can be traced for 30 to 40 yards along the road, but want of exposures makes it difficult to estimate its probable extent.

(ii) About half a mile north of a little village called Twinnge, which lies a little over two miles due north of Thongdaung Railway Station on the Mandalay-Kunlon Railway, is a hill whose top, *i.e.*, so much of it as is exposed, shows masses of a very rich iron ore, probably hæmatite with magnetite. The surfaces of the masses of the ore are seen covered with minute magnetic, needlelike rods which move about as one passes one's hammer over them. There is no doubt that it is a very rich stuff, but the ground around and about the hills must be a little more cleared before one could estimate with any degree of certainty as to the quantity of the ore here, which is apparently large.

(iii) Some ferruginous rock was seen by the Wetwin village, about the 55th milepost on the cart-road, apparently bedded and underlying the Wetwin fossiliferous shale. I saw this rock again about a mile and a half east by north of Wetwin. So this is in all likelihood a ferruginous band of ironstone occurring associated with the shales here.

(2) *Limestone.*—This rock, it is needless to say, occurs here extensively:—

(*i*) It is being used for road metal.
(*ii*) It can be, and is being, utilized for making lime.
(*iii*) When selected it would also, no doubt, make good building stones.

Report *on a* Geological Reconnaissance *in* parts *of the* Southern Shan States *and* Karenni, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

CONTENTS.

I.—General Remarks.

Objects and method of tour.

The notes which follow were made during a short season's tour (from early in December 1899 to the end of March 1900), and do not pretend to be anything more than rough geological jottings. My object was to cover as much ground as I could in the allotted time, and to ascertain the possibilities of the country, rather than to make even a sketch-survey. No attempt at detailed mapping was made. My marches generally were either daily or with one day's halt—but rarely more than one. They were also made along definite lines across the country, the shortest routes in fact available.

Present difficulties in the way of a detailed survey.

In most parts visited a more elaborate survey would, for the present, have been out of place. For, firstly, the country, which has only been indirectly administered by our Government for thirteen years, is not yet one in which the searcher after scientific facts can feel entirely at home. He is hardly allowed to travel by himself and as he lists. In some cases he must have a police-guard or even a military escort. He is still liable to be treated as a guest by the people of the states, and his actions consequently hampered in a multitude of easily-imagined ways by all that is implied by the word guest. With all laudable intentions the native state officials seek to make much of him—to meet him with processions, to call upon him with gifts, in and out of season. Secondly, the physical conditions of the country through which I passed are against detailed work, at least at present; whilst over much of the area, unless useful minerals are found, I am of opinion that any approach to real geological mapping cannot advantageously be done. These physical conditions briefly stated are: (1) heavy jungle and sparseness of footpaths, except along the higher and flatter plateaux, which necessitate the geologist keeping to arbitrary beaten tracks: (2) scarcity of villages and supplies with the exception of the plateaux noted above; and which again necessitates a pre-arranged plan of tour, and one that must be kept to at least generally, in spite of vagaries of the rocks (this is notably the case in Karenni): (3) the nature of the dominant rock formation, which being a massive limestone presents all imaginable difficulties to the stratigraphist, chief among which are absence of

distinct bedding, irregular weathering, chaos arising from underground drainage, local subsidences and the rareness of erosion channels exposing anything but tumbled blocks; absence of striking petrological horizons that would help out the last difficulty if present by furnishing a key to their unravellment; and last, but not least, the absence of railway-cuttings and road-cuttings, except in the solitary case of the Government cart-road from Thazi to Möng Pawn. This last is really of more consequence than it seems, especially when it is considered in connection with the nature of the rock; for the tendency on every hill-side is for the thin-bedded shaly layers (which are the most likely to yield recognizable fossils) to be completely obscured by the chaotic tumbled blocks and the thick surface clay into which they weather.

In the third place, though much of the southern Shan States has been topographically mapped on the 1 inch = 1 mile scale, some of it, and especially Karenni, has to be content with nothing more advanced than the ¼ inch = 1 mile reconnaissance sheets, which in hilly forest-covered country are almost useless for geological purposes. In the fourth place, beyond the narrow zone of crystalline igneous and metamorphic rocks fronting the Irrawaddy plain, there are no igneous rocks whatever in the area visited by me, neither bosses, dykes, nor contemporaneous volcanic flows. Thus all interest centering in pure petrological work has no scope in this part of Burma.

In spite of the above rather formidable array of difficulties in the way of an elaborate geological survey, as understood generally, it is hoped that the results I have obtained, sketchy as they are, will at least lift the veil of ignorance under which its geology has hitherto lain; and, taken together with Messrs. La Touche and Datta's recent work further north, furnish a rough guide to the general geology of part of this eastern frontier of the empire.

Obligations.

Owing, as already stated, to the political disabilities which obtain in these frontier parts of our empire, my traverses, except along the bungalow-studded Government cart-road, were somewhat of the nature of personally conducted tours, made under the auspices of one or other of the civil officers in charge of the native states. For the arranging of these I have to express my great obligation to Mr. A. H. Hildebrand, C.I.E., Superintendent and Political Officer of the southern Shan

States, who (at rather short notice) gave me most efficient help. To Mr. C. E. Browne, Extra Assistant Commissioner of the Myelat, I am indebted for his taking charge of me during the early part of my tour, and for his personal interest in and carefully collected data about, the mineral wealth of the states under his care; and to Mr. W. G. Wooster, Assistant Political Officer of Karenni, who took me over from Mr. Browne and piloted me pleasantly and successfully through the Karenni country, and saw me across the Toungoo border. To the above especially, and to several other civil officers resident in Taunggyi in a less degree, I have to tend my best thanks for many courtesies and kindnesses received in this, to me, rather strange land.

Previous work in this area.

Although the greater part of the country traversed by me was geologically unknown, a few localities had been rapidly visited by my late colleague, Mr. E. J. Jones, A.R.S.M., in 1887, for the purpose of investigating the coal, lignite and other minerals there found. His results are given in Records, Geological Survey of India, Vol. XX, Part 4, 1887, pages 177-194. His operations were conducted under conditions far less favourable than mine, and at a time when the country was only just recovering from anarchy and from harassment by dacoit bands. Furthermore, the only map he possessed was on the scale of $\frac{1}{16}$ inch = 1 mile. Hence he made no attempt to delineate the formations or to generalize his geological data, and confined his notes strictly to the mineral occurrences which he investigated. Dr. F. Noetling in more recent years paid some similar brief visits to the country immediately to the north of my area, and has published his notes in Records, Geological Survey of India, Vol XXIV, Part 2, page 103. Mr. La Touche, who contemporaneously with me has now been visiting the northern Shan States, has added to and amplified the above geological data. He is reporting on his work so that I need not recapitulate them here. In the Manual of the Geology of India, 2nd edition, page 142, a brief allusion is made to the probable continuation north along the Salween river of the Moulmein carboniferous limestone.

So far as I know, the above embody all the co-ordinated information that has been gathered by qualified geologists in this area.

II.—Physical Geology and General Tectonic Features of the Area.

Before describing the traverses I have made through the area, it will be well to state shortly and comprehensively for the whole of that area such salient facts as to the physical geology and the general style of rock architecture, and tectonic geology as, notwithstanding the poor sections and absence of striking stratigraphical horizons, have nevertheless made themselves sufficiently evident to me.

A great elevated compound zone of formation.

To begin with, the whole earth's crust of this part is a great elevated compound zone of disturbed rocks comprising three or four minor stratigraphical or compositional zones. It consequently is a region of special upheaval resembling the Himalayas, and embraces hill-ranges of considerable height; all, however, in this latitude well below snow level and the influence of ice in any form.

Hill-ranges and valleys.

The hill-ranges run mainly in directions roughly north and south, and are divided by eroded longitudinal valleys of, as a rule, no very great steepness except in the case of the Salween and Pawn rivers. The minor parallel streams are frequently very irregular and indiscriminate in their courses, complicated as they are by sudden underground disappearances, and by sharp cross branches which dash through gorges at right angles to the ridges and may then turn either north or south.

Plateau aspect.

Except for the larger and deeper valleys just mentioned the greater part of the area I have crossed, besides being characterized by parallel hill-ranges and valleys, is as a whole of an elevated plateau aspect. Wherever great masses of the limestone formation are in force they build scarps and plateaux in numerous array—a result which may in many cases be seen to be due to a roughly rolling dip of the great thick-bedded formation, but in other cases is helped out by sub-recent or uppermost tertiary deposits infilling what were once shallow valleys between alternate scarps.

Amount of folding and compression of the area uncertain.

But with all this I have not been able to gauge the approximate compression, folding, and faulting that have actually taken place. For it is impossible without distinct bedding and marked fossil, petrolo-

gical, or colour horizons to distinguish a series of superposed and closely packed overfolds, sigmaflexures and lying anticlinals and synclinals from a gently undulating series of normal folds.

That, however, the plateaux are not altogether simple, normal undulations of a vertically elevated block of strata, seems indirectly certain from a variety of considerations. In the first place there are the remarkably straight boundaries between different formations; there is also the tendency to a universally oriented strike whenever it can be observed, and, as a corollary to the above, an arrangement of the formations in straight bands and a (broadly speaking) settled sequence of them from west to east wherever a line of section is taken.

Hence, this Southern Shan plateau differs somewhat from a typical table-land, and possesses some of the characteristics of mountain areas like the Himalayas, which have suffered distinct sets of lateral compressions at different times with crumpling and possibly overthrust accompanying such. But along with this qualitative statement it is quite impossible at present to write down how much, and to what extent, these earth movements have progressed.

III.—STRATIGRAPHICAL AND COMPOSITIONAL ZONES.

As already stated, the geological fabric of these hills may be split up into a number of steadily striking zones or bands, of distinctive character as regards stratigraphy and composition. They lie parallel to one another, and they generally outcrop in a definite order from west to east. Although the imperfections of the sections give no clue to the exact style and amount of folding, and by consequence no evidence as to the relative positions of these distinctive bands in the geological record, there are other considerations which enable us to place them provisionally in the following order of time sequence :—

Order of Zones.

(1) Gneissic and Metamorphic Zone.
(2) Great Limestone Zone.
(3) Purple Sandstone Zone.
(4) Sub-recent conglomerates, sands, and loams.

(1) *Gneissic and Metamorphic Zone.*

Archæan, intrusive, and metamorphic facies.

I am compelled to put this as the oldest of the sequence because of its archæan facies in part. In many ways it presents an appearance of great age, for it contains true gneisses with intrusive plutonic veins, and also much metamorphosed, foliated, cleaved, and cataclastic rocks.

Area of zone confined to west side of plateau.

So far as I have observed, it is confined entirely to the western edge of the described area, and, though not politically included with the southern Shan States, it forms topographically the western front of the Shan States plateau.

Surface features.

This western edge rises sharply from the alluvium-covered plains which form part of the Meiktila, Yamethin, and Toungoo Districts and along which, in full view of the gneissic zone, runs the railway from Rangoon northwards. As seen from near Thazi railway station, the near hill-sides, spurs and ravines of this elevated zone give evidence of free sculpturing at the hand of time. Their towering, sharp-edged ridges, with wide and deep gorges and flowing slopes between, show up remarkably like much of the older zones of the Lower Himalayas. Degradation is evidently accomplishing its work, and the thin, acute-angled, irregular, and vermiform summit ridges are being scored and fretted away into all those shapes so characteristic of a relatively old land area—a condition only antecedent to complete extinction.

Nature of western edge of Zone.

What is the structural relation that this zone bears to the alluvium-covered pliocene and miocene plain at its foot? Without any younger foot-hills separating the two, the straight unwavering western margin of the zone probably indicates a north—south fault. According as we attribute great intensity or not to the crumpling forces which upheaved the plateau, so must we regard this fault as a fold-fault or a simple upthrow fault. In any case it is likely that it was not a sudden disruption of tertiary age, but a line of more or less continuous movement that went on for long ages during the geological history of this part of Burma.

This gneissic and metamorphic zone is of narrow dimensions compared with the great expanse of rolling plateau further east. In the cross-section from Hlaingdet to Pyinnyaung it is about twelve miles, the first four of which are gneissic.

Width of the zone.

The gneissic rocks, as seen in the road cuttings about seven miles from Hlaingdet, and as found in fragments here and there on the hill-slopes and talus fans, are not unlike many of the mixed gneisses of Salem and Coimbatore in the Madras Presidency. They are well foliated, micaceous, and hornblendic gneisses. Intrusive among them are veins of pink syenite, white pegmatitic granite and fine grey micro-granite containing biotite and muscovite. These veins are non-foliated, and have been intruded across the foliation of the gneisses. No other good exposures of these rocks are seen on the road.

Petrography of the zone.

At the 18th milestone from Hlaingdet where the cart-road from the valley begins to wind among the hills towards Yenmabin there set in sub-metamorphic quartzites and slates. All are much smashed by earth crushings which have splintered them or split them up into platy layers. In this respect these rocks have a remarkable Himalayan facies. Near Yenmabin a fine-grained gneiss occurs and some pale coloured quartz felsites or micro-granites. East of Yenmabin the white quartzites and slaty rocks are less metamorphosed, and plainly indicate their sedimentary origin. Interbedded with them are occasional very thin bands of dark blue-grey limestone a foot or two wide. All are very much smashed. Further north-east towards Pyinnyaung greenish grey dark quartzites and black slaty sub-schistose rocks continue—all much fractured—and there are repetitions of all the rocks from Yenmabin over again. Near Yebokson there is a green and white mottled gneiss.

East of Toungoo a section across this same zone from west to east is much more unsatisfactory from the fact that there are no road-cuttings and the surface exposures are extremely rare. There are evidences in the stream-beds, however, showing that gneissic rocks, quartz-schists, and other metamorphic strata are there found. A large development of a very coarse unfoliated porphyritic granite is seen to the west of Leiktho. It weathers into gigantic rounded boulders, destitute of foliation or banding and contains hornblende and black mica. The eastern edge of this zone cannot be very

definitely placed, but it must come somewhere near the longitude of Yado.

(2) *Great Limestone Zone.*

The most characteristic formation in the southern Shan States.

In a very wide sense this zone may be considered as the only other one existing. It is in fact, *the* characteristic zone of the Shan plateau proper. Nevertheless it is partially interrupted along certain lines by two other distinct minor stratigraphical zones presently to be described. At one time during the progress of my work I had hoped to further divide the great limestone zone into sub-zones of separate geological age and of slightly different composition. Further work south of the Government cart-road has, however, shown me that even if any differences might be made on palæontological or petrological grounds (as to which no positive evidence is yet forthcoming) the rocks could not certainly be traced north and south in recognizable bands in the same definite order that I consider necessary if they are to be judged of any value as structure zones that imply anything vital regarding the evolution of the mountain mass.

Surface features.

Every traveller and dweller in the Shan States must be aware of the characteristic features of this great calcareous zone. Though thrown into ridges and minor mountain chains, it has a general elevation that makes it enjoy a pleasant climate for several months of the year. The sun during the dry months may be hot by day, and rise and set over the billowy table-land with a fervidness unknown in less arid parts, but the nights are cold, and frost in December and January is quite a common thing. It supports a hardy population of various hill races, very different from the low-country Burman, and all speaking different tongues. It might, and probably in time will, if judiciously fostered, grow crops of cereals, vegetables, and fruits to supply Lower Burma markets, when the communications with the plains are improved and further extended. Its forests, in favoured places in the greater river-ways, are well known already for the teak and other minor forest produce that they yield.

In its essentials, and not considering the younger minor zones that are inlaid with it, it is a rugged, rocky country. The dark grey limestone frequently weathers almost black into sharp-edged honey-combed masses, into pinnacled crags and weather-beaten towers and

walls : into deep basins and swallow-holes (often as regular and circular in outline as a gigantic amphitheatre, but sometimes funnel-shaped) : into strange valley systems without connection one with the other, and that often end mysteriously either as underground passages down which streams precipitate themselves and become lost, or as marshes and lakes where evaporation helped out no doubt by subterranean percolation causes a disappearance of the waters : into innumerable caves and passages beneath the ground, some now high and dry from the waters that caused them and which are locally mined for the nitrates that have accumulated upon the floors from the decomposition of cave animal deposits, others used as show places and temples ; others again unknown to fame and rich in their virgin beauty of stalactitic growths.

In other words the surface of this great zone has that configuration which is everywhere characteristic of massive limestone, grim aspects which in other countries would mark out the arch-enemy of mankind as its far-back land owner, and aspects which by some inscrutable wrong-headedness in lightly-thinking people are often attributed to volcanic agencies.

Except, however, in the upland valleys and the deep gorges, the sponge-like absorption that it exercises on the rainfall carries off nearly all the surface waters ; so that, at least in the dry months, the ridges and slopes are generally devoid of rippling brooks and streams. What becomes of all the aerial moisture discharged on it ? Perhaps in some cases a great deal is led away by underground river systems that lower down emerge into the larger and deeper river gorges. Some such underground connection is popularly supposed to exist between the Balu Chaung or Loikaw river and the Pawn. But, in the majority of cases, I believe the great network of hidden streams and torrents that run their underground courses never again emerge to the light of day, but continue ever downward till their watery burden reaching the lower heated layers of the earth's crust becomes absorbed in the aqueo-igneous fusion of deep-seated earth magmas.

In all these respects this great limestone zone presents a striking contrast to the gneissic and metamorphic zone ; and nowhere is this better exemplified than on either side of the Toungoo-Karenni border. To the east roads and halting-places are restricted by the limited supply of drinking-water for man and animals, whilst still

further to the east, even the great Salween and Pawn valleys, except for the immediate edge of the rapidly flowing flood, are in the dry months over large areas destitute of water and of green vegetation. Nothing is so forbidding to the traveller as the steeply graded slopes black with the ashes and charred remains of the ever-prevalent forest fires and the stems of the stunted forest growth that rise above him on either hand. Not a bird in the leafless trees, not a grub in the ash-strewn land, and not a fish in the river! The skeleton forest is not more silent and gloomy than the limpid depths of the river are tenantless. But to the west of Yado the metamorphic zone is well supplied with the life-giving liquid, rippling streams and moderate rivers are everywhere found. It possesses a thick carpet of surface soil densely covered with dark evergreen forests and alive with bird, beast, and insect at all times of the year.

Of course these statements must not be accepted as universal and sweeping in application. Among the great limestone plateaux may be found many fertile valleys; because, perchance, they run along one or other of the inlaid zones of younger formations; or because they possess an abundant supply of water kept by a lining of recent alluvium from escaping away through rifts in the valley bottoms; or because of some interbanded shaly layer associated with the limestone (a not uncommon occurrence). The general truth, however, remains as stated; and I believe that as time goes on the contrast will be more and more evident, until at last many tracts of the great gaunt plateau of the Shan Hills, having lost their surface soil and younger valley deposits by further denudation, will become mere dried-up porous transmitters of their rainfall to subterranean depths, whilst the lower plainward zone will become more and more verdant and richer in tropical forest.

But this is in the far distant future viewed through geological spectacles. From a human point of view it will be a long, long time before the plateau even partially suffers such a death as this; and the end may for all practical purposes be kept at a distance by conserving the present forests, increasing the rainfall, economizing the water-supply, and leading it by irrigation canals over as large an area as possible.

Petrography: Section along the Government cart-road.

Owing to the very fair set of artificial sections exposed along the cuttings in the Government cart-road from Pyinnyaung to Möng Pawn, which I had the good fortune to see before time had

sloped them back or covered them with vegetation, this line of section and its continuation further east along a good bridle-road from Möng Pawn to Nongsewik is the best exponent of the structure and lithology of the formations composing it. I shall, therefore, first illustrate the petrography of the limestone zone by describing that section. In the description certain tentative groupings of the strata will come out, but as they were not elsewhere recognizable in a similar cross-section further to the south in Karenni, where no artificial cuttings were present to help, I have not coloured them separately on the map, save that the bands containing fossils have been added in a deeper tint of the same colour.

Pyinnyaung limestone.

Beginning at the first massive limestone that appears most westerly in the section, we find a little east of Pyinnyaung a set of towering crags forming a long ridge densely covered with forest and lifted high above the surrounding country. This band of limestone is isolated from other bands to the eastward by other rocks afterwards to be described. Whether it is of a different age to those limestones or not cannot be certainly stated. The band runs a perfectly straight course north and south. Through it in a narrow gloomy defile dashes the Pyinnyaung river by a cross rift, exposing the rock on both sides. The rock is dark and light blue-grey, massive, compact, and but slightly brecciated with recementation by calcite veins. One can see no definite bedding in it and no regular variety in its composition. Only by the absence of any apparent V-ing of the western outcrop across the gorge can one judge that its dip is at least very high. The ridge possesses very steep rugged slopes littered with titanic blocks, all emphasizing its very massive character. After many experiences in the Himalayas I would compare it with any one of the massive limestones or dolomites so common in the outer Himalayan belt. *e.g.*, the Naini Tal, Krol, and the Trias of Hazara. The gorge is about one mile long through the limestone. How much of this is direct ascent or descent in the obscure stratification, or how much folding has taken place it is impossible to say. A search for fossils was unrewarded, though much of the rock might well have been fossiliferous, judging by its compact non-crystalline state.

The same band can be seen stretching away north and south for many miles. I did not trace it or cross it again, but obtained a near view of the southern continuation of it west of Kindaung, by a traverse from Kalaw.

But it is not until having ascended to and passed Kalaw on the cart-road that one finds oneself really among the great limestone plateau. From there onwards limestone is never entirely absent from the section, the whole way across as far as I explored, namely, to Nongsewik.

Thamakan limestone.

The first recognisable unit in this great spread of calcareous formation begins about 10 miles west-south-west of Thamakan, and extends under the Thamakan plain to the west side of the Heho valley. It may be called for convenience the Thamakan limestone. It is of a rather pale neutral-grey colour, massive in places, but also thin-bedded and marly and shaly in places. Occasionally it is sandy. It bears a great resemblance to the grey limestone of Hazara, which underlies the recognisable and concretionary nummulitic limestone. From its interbandings with the thin grey shales and marls and its appearance of no great metamorphism I went about confidently expecting to get fossils at every step. Nevertheless none were found. I hammered every inch of the exposures in the cuttings during two journeys forward and backward across it but all to no purpose. The undulating surface of the plain and the low hills fringing it west and east show here a scarp and there a low dip-slope, apparently all of them fairly gentle as if a billowy broadly extended synclinal was the form the rocks here took. In the low hills west and north-west of Thamakan shales and marly beds are very prominent, and flowing moulded slopes the rule. To the east the descent into the Heho valley is very plainly a scarp with gentle dips to the west of not more than 30°, and the prevalent rock here is limestone with but few shales. The flatter plain in between, though often exposing the limestone to view, is generally occupied with newer nearly horizontal strata to be afterwards described. This plain at about 4,000 feet is generally dry and arid and bare of forest save a few bamboo clumps round about the monasteries.

Heho limestone.

Continuing the road section eastwards we first cross the flat alluvial stretch of the Heho plain, and a ¼ mile east of Heho village enter upon the next member of the great limestone zone, which from certain peculiarities may be distinctively called the Heho limestone. In colour it is rather darker than the Thamakan limestone, of a blue-grey tint within, but weathering greenish grey to a considerable depth. It is as a whole rather inclined to be well bedded, as can be seen in

the road sections, is sometimes semi-concretionary and but very seldom brecciated to any extent. It is interbanded with pale shaly and marly layers. A noticeable structure in the limestone is that it possesses thin interbandings of ferruginous layers ¼ inch wide which stand out from the greenish grey limestone in marked ragged relief. In some cases as near Heho these ferruginous layers may be seen to consist of compacted shelly layers. There is just enough evidence to show that some form of molluscan life had there been present, but no more. None of the shells could be isolated or identified even genetically.

Good exposures of this limestone are found from Heho down the rather steep ghât to the Sinhe plain, which is the northern continuation of the Fort Stedman lake valley. The dips are at first to the east at rather low angles, after which there is a rolling or contorted dip either way.

Taunggyi-Hopong-Htam Sang limestone (permian in part).

The flat or gently rolling plain about Sinhe makes the next gap in our road section, which begins again with the ascent to Taunggyi. From here onwards to the Pawn river is a diversified mass of hill and flat upland plain showing great variety of limestone and associated thinner bedded shales and a few sandy limestones. This lot is grouped together here not because they are all alike, but because I cannot devise any rational separation of them. They may be entirely distinct in age from the 3 groups already described or they may contain them all, but altered beyond recognition by subsequent cataclastic action—for this is a striking feature of a great many of these minor rock bands that they have been so crushed, brecciated and recemented again that for all intents and purposes a new rock has arisen. In such layers of course no fossils have been preserved, but as we shall see presently the more eastern part of this group abounds in favoured places with remains of organisms of middle productus limestone (permian) age, which for some unexplained reason have here been able to declare themselves.

The ascent to Taunggyi is a zigzag up a scarp, the counterpart of the descent from Heho, except that it is considerably higher, especially if the summit of the wall-like crag dominating Taunggyi be taken in. The latter is as it were a second storey planted on and a little back and east of the first line of crags and with the new settlement of Taunggyi occupying a gentle hollow between, Taunggy

at a height of 4,675 feet is the head-quarters of the Government of the southern Shan States, a pleasant nucleus of a hill-station now, but given a railway communication with Burma proper, it would be capable of rapid development. There is water in abundance, a fertile soil that can produce—well almost anything that the gardener wills. The Government garden now in full swing is an earnest of what it can do, and I have memories (hardly perhaps fitting to enlarge upon here) of strawberries and potatoes obtained therefrom that will never fade.

The climb by the road up the lower scarp is a revelation of what a rock can suffer under earth stresses. Taunggyi, "the big hill," and all the other great heights between it and the Pawn river were hove up to their present level at no small cost to the foundations thereof. Almost every mile of the way is a record of brecciated, crushed and churned rock stuff that has however mostly set again into a kind of angular concrete. Some of it is white, some pinkish and some grey and sandy in texture, while some few bands intercalated between a cushion of shales, and which have alone escaped the general crushing, look as though a prolonged search in them might yield fossils. My brief search was however fruitless The crags forming the scarp at the base of the hill have a general dip of 30° east. Those at the summit building the pagoda-topped hill seem to have a general horizontality, but undulating. The general horizontality continues eastwards to Mania Sut and Maik Taung. Near Pa Leng and south-west of Hopông the north—south ridges have their strata very definitely dipping east-north-east at a low angle; and the topmost beds of these hills are very massive grey limestone. All these slopes down to Hopông are, in fact, dip-slopes, gradually lowering in angle and passing under the flat or gently flowing valley of Hopông.

Continuing the section again, still ever eastwards, beyond Hopông we find the limestones, still grey in colour, recovering and soon dipping at very low angles in the opposite direction, namely west. In other words, we have crossed a flat synclinal fold. As far as the 18th milestone from Taunggyi the gentle westerly dip continues in rather crushed sandy, white limestone, also grey and banded with pink. The exposures are not continuous the whole way, but are only found here and there in isolated lines of crags with flat terrace-like valleys between. Beyond the 18th milestone we get

among larger craggy ridges which also become massed together. The road ascends more steeply and zigzags round many rocky spurs up to the pass at the 21st milestone. As far as the 20th mile things are obscure, the dip is irregular and high, the limestone crushed and powdery. From 20 to 21, however, comes a change. There are steep dips to the west in somewhat concretionary limestone with cherty lumps and blotches of crystalline calcite. Then follow dips to the east at 30 to 40 degrees in grey shales and interbedded concretionary limestone and marls.

Fossils.

In these rocks, between 20-5 and 20-6, I first found fossils (localities 1 and 2). They made their appearance on weathered surfaces in the form of corals, crinoid stems, and brachiopoda (chiefly *Athyris sp.*) They were not very remarkable in numbers or preservation, and they were mostly impossible of extraction, but at last real fossils were in evidence. Two points about the fossiliferous zones are worthy of note: (1) They are generally thinner banded, semi-concretionary limestones in the vicinity of shales; or (2) shaly and marly layers. To work the former it is necessary to wrench away or chip off a surface layer of the hard limestone. As to the latter, the best method of search is to wander along the sloped cutting in its freshly weathered state, when a good collection (of brachiopoda chiefly) may be picked out with the fingers from the crumbling loosened surface.

At the 21st milestone the road begins to descend regularly towards Htam Săng. We cross a little pass and get on the other side of the ridge. We now have before us a course of dark grey fissile shales dipping at 30 to 40 degrees to the east with one or two thin quartzitic and somewhat calcareous layers. These shales weather a pale buff or khaki colour. I could find no definite fossils, only some somewhat peculiar vermicular markings (locality 3).

• Past milestone 22 with an intervening bit of covered ground, the road still descends a similar section with a few limestone bands, till near 23 miles 5 furlongs when we are rewarded by a fine section, 35 yards wide, in thin-bedded, concretionary-tabular bryozoan limestones with the usual interbedded marly and shaly layers, all packed with fossils, bryozoa, corals and brachiopoda (locality 3 *a*). The dip is as before. So far though no very characteristic and well-preserved specimens have been obtained, they suggest a middle productus limestone age.

On again past the 24th milestone, through more shales and calcareous layers till milestone 24, when for half a mile the rocks exposed are alternations of shales, marls, and concretionary-tabular limestone containing a fair abundance of corals, bryozoa, and brachiopoda (locality 4), the latter being again found in crops on the rain-loosened surface of the weathered shales as at locality 2. Among them appear several species of *Athyris cf. roysii* and *Spirigerella cf. derbyi* together with a quantity of *Chonetes grandicosta* and a few specimens of *Spiriferina cristata*, all of which are characteristic of the middle productus limestone of the Salt Range.

As we near the 25th milestone the limestone asserts itself again more massively, mostly in white, grey, and pinkish layers, very much crushed, brecciated, and probably much folded and faulted, though how much one cannot say. No fossils. Then we pass the bungalow at Htam Sāng and get down to the river-bed at 25 miles 4 furlongs. Just here is a natural bridge or covering in of the stream-bed, a limestone bridge, left like a snow bridge spanning the chasm. In the neighbourhood are said to be many caves. The road now ascends again following the river and climbing high above it to 26-3. It cuts through more of the crushed and crumbling white and sometimes pinkish limestone, in which only a vague general stratification apart from the shear planes can be recognized. It becomes dazzlingly white among the higher beds. Beyond 26-3 there is a short space without exposures, and at 26-4 appears concretionary-tabular grey limestone in thin bands among black shaly layers. This is fossil locality No. 5. For about 10 feet in the middle it is rich in fossils in the shaly or marly layers. Particularly noticeable among the fossils are large and small specimens of *Spirifer musakhelensis*, one specimen of *Productus cf. indicus* and of *Spiriferina cristata*, large numbers of *Chonetes sp.*, among which are *ch. grandicosta* and *ch. dichotoma*. All these are eminently characteristic of the middle productus limestone.

All the above may be extracted from the rock in the cutting, or picked up on the talus slopes on and below the roadway. Above and below the richer 10 feet there are 50 to 60 feet of less rich layers containing principally crinoids, corals, and bryozoa.

Up to and beyond 26-5 there next come some dark grey, splintery, much crushed shales, in which no fossils were found. Apparently a fault then intervenes, and what appears to be the last series over

again from the stream is repeated, but the amount of the crushed grey and white limestones is not so great. Among it occurs a purple band of shaly limestone. The concretionary grey limestone with interbanded shales is marked by a number of chert nodules and an absence here of fossils.

The strike of the whole of this series is about north-west to south-east and the dip north-east. Beyond milestone 26-7 the road turns more easterly and curves round a hill-spur passing for a long distance through splintery shales, which as a whole seem unfossiliferous. They are generally drab, but sometimes dark grey, and they weather paler colours. They are sub-concretionary and soft. The only fossils I found in them were an ill-preserved cast of portion of a nautilus between miles 29 and 30 (locality 5*a*), some indistinct white vermicular markings just east of 30th milestone (locality 5*b*), and an impression of part of a trilobite, a gastropod, and more vermicular markings at 30-2 (locality 5*c*). It is impossible to say regarding these shales whether they are a series separate to and older than the middle productus limestone series or not. The fossil evidence is too imperfect. These shales, interrupted locally by some of the red sandstones of zone 3 and soft pale sands and loams of zone 4 continue along the road, which keeps at a low level, constantly descending, until Möng Pawn is nearly reached, when close to the bridgeworks over the Pawn river there comes in, as if suddenly by a fault, some well-bedded concretionary tabular limestones and shales forming a low cliff running about north to south and edging the Pawn river. The interbanded shales contain many brachiopoda chiefly *Orthis indica* (locality 6). But although nothing but shales were met along the road up to this point from milestone 27, the cliffs above towards the south showed signs of the presence of the massive limestone at several points, doubtless repeated by folds and faults. Dr. F. Noetling, who has kindly helped me with my fossils, thinks that the whole of the fossiliferous series above, with the exception of those of localities 3, 5*a*, 5*b*, and 5*c*, are undoubtedly of one age and certainly belong to the middle productus limestone of the Salt Range (permian of Europe).

The wide valley of the Pawn river now makes a gap in the section, which is also complicated by the sub-recent valley deposits of zone 4. To the east of this valley the section takes us by a bridle-road up and over a lofty range, the Loi Sampu, about 5,000 feet.

For the first-half of the ascent grey, sometimes concretionary, shales, which sometimes become sandy and of a dazzlingly white or pale pink colour, dip steadily at moderate angles (about 30°) to the west or east.

Loi Sampu limestone.

There is, then, a rather sudden change and shales and interbanded limestones, the latter containing layers of compacted shells, dip more steeply to the east. At the crest of the ridge there are some few purple shales in evidence and then comes the steep descent towards Bamping over rugged dip-slopes of more limestone resembling that near Heho and containing a few compacted shelly layers and sandy shaly layers.

Bamping-Nongsewik limestone.

From Bamping east there is a low-lying, gently undulating plain, broken further east near Nongsewik by a few isolated low hills and groups of hills. These all show moulded dip curves to the west and scarped crags towards the east with low dips in a light grey limestone resembling that of Thamakan. It shows a slight tendency to a more crystalline condition. Away to the east the vast plain, dotted with a few hills, continues. It undulates and is grass-grown with a few clumps of pipal trees, etc.

This is the farthest point in an easterly direction that I reached and brings the description of this section to an end.

The limestone zone as a whole.

Considering the great limestone zone altogether as exhibited in the cart-road section we see that with a tolerable uniformity of strike, and with locally recognizable dips and successions of the strata, there are still great gaps at important places and much uncertainty as to the amount of repetition and re-duplication by faulting and folding, especially along the areas of brecciated rock. It is, therefore, impossible to rationally build up a continuous section with all the strata arranged in correct stratigraphical succession. We can only guess as to the proper relative position of many of them. For the same reason it is impossible to gauge the thicknesses of the limestones individually or collectively. We know that they must be very thick, as their base is never reached, but that is all.

There is, however, a certain surface succession to be made out among them in the area between Thamakan and Nongsewik. There is a large central part characterized by fossiliferous bands

of middle productus limestone age. On the one side of it, east of Heho, and on the other side of it, east of Möng Pawn, there is a peculiar rather well-bedded limestone with faintly preserved layers of unrecognizable compacted shells, whilst outside each of these again come the similar pale grey limestones of Thamakan, on the one hand, and Nongsewik on the other.

The surface symmetry of this arrangement can only be pointed out here. When more and better sections and detailed work have been accomplished the above may be found to harmonize with some plausible theory as to the full order of sequence of all the strata and the particular nature of the earth-folds that are responsible for that arrangement.

Other sections.

Besides the extended cross-section along the Government cart-road just described, my subsequent work in this zone includes (*a*) a few cross and strike traverses north of Thamakan extending as far as Myinkyardo and Bawzaing; (*b*) a route traverse along the strike south of Thamakan to Loikaw in Karenni; and (*c*) a long cross-section in Karenni from the Salween river to near Yado—a distance of about fifty miles in a direct line. The last, it was hoped, would have proved most important, as it was a parallel traverse to the one along the cart-road, and I naturally hoped to again pick up the same sequence of rocks as on the cart-road. Such, however, was by no means realized. The other two sets of minor traverses may first be described.

The Thamakan limestone with shale bands is known to extend northwards as far as Myinkyardo and probably much farther. The comparatively level sweep of country by Kyon, Nankon, and Myinkyardo shows here and there this limestone emerging and forming lines of rocky heights. These enlarge and close up somewhat towards the west edge of the plateau and then the country rapidly falls away in riven and shattered scarps to much lower levels. The same limestone and shales as seen in the scarp east of Thamakan, and facing the Heho valley, take a parallel northward direction as far as Pwehla and the low hills east and north of that place. The Pwehla line of scarps are very prominent, while the low barren and waterless hills to the east and down to Kyauktat are obviously (as illustrated unmistakably by their curves) onward flowing billows of the same gently flexured limestone as they

gradually descend towards the northward and north-westward continuation of the Heho limestone.

The mass of elevated hilly country between Myinkyardo and Pindaya is of the nature of a much disturbed anticlinal and is composed of limestone and shales generally of the well-bedded Heho type with compacted shelly layers. The same appears to hold for the hills east of Pindaya forming the Bawzaing group, and those east of Kyauktat running down to Heho. Some of the limestone, however, immediately west and two or three miles to the north-east of Pindaya contain recognizable crinoids and corals resembling those of the middle productus limestone group further east. In general, however, beyond the immediate neighbourhood of Thamakan, either north or south, the evidence for any good distinction among the limestones is, as already stated, very weak owing to want of good sections.

Similar limestones and shales without any characteristic distinctions, but plainly belonging to one or other of the three nominal divisions, extend for long distances south of the Thamakān-Möng Pawn cart-road, and compose the greater part of the plateau and hilly masses which continue to the south of Karenni. Between Thamakan and Loikaw I only traversed this country along the strike of the rocks, with a few short cross-traverses, consequently the limestone zone was only seen here along the narrow width of a few miles.

But from Loikaw in the Karenni country I made traverses east over high ridges and low valleys as far as the Salween river, down the Salween as far as Ywathit, thence westwards again over the southern continuation of the same ridges to Saulôn and Nwedaung, and thence west-south-west across a complicated hilly mass to Yado. I thus covered a breadth of country 45 to 50 miles wide across the strike. Here also I found that similar limestones and shales with a few quartzites, equally inseparable as to their individual formations, occupy almost the whole country. Their strike continues to be roughly north and south as before; they pass through the same variations of colour and brecciation as before; their exact manner of folding is equally indecipherable as before. The only local differences that can be detected are that in a little range of hills immediately south of Loikaw, and also near Saulôn, there occur some limestones and shaly limestones with crinoids, corals,

and brachiopods, ill preserved but generally resembling those near Pindaya; and that all sections east of the Pawn river display the limestones and shales, which become gradually more metamorphosed until, at the longitude of Hsataw and Ywathit, snow-white and grey marble take the place of the ordinary limestone, while schistose slates take the place of the thinner-bedded layers. Along the west side of the ridge east of the Pawn there occurs also a band of quartzite and schistose slate and, doubtless the same repeated, in a line from east of Hsataw to Ywathit. It is but fair to add, however, that in some places the rocks are hardly exposed at all, *e.g.*, between Loikaw and a few miles west of the Pawn river where immense blanks occur without a single rock appearing above the surface soil and the low burnt scraggy jungle, and also along the obscure junction line between the great limestone zone and the gneissic zone near Yado, where from the surface soil and weathered surface rock it is impossible to say whether we are upon old weathered quartzitic rocks or the younger purple sandstones of zone 3.

(3) *Purple Sandstone Zone.*

A minor zone of the great limestone one.

As has already been said, the great limestone zone is interrupted by, or inlaid with, one or two minor compositional zones of younger age which are here and there repeated. The purple sandstone zone (or zones, counting its reduplications) is made up of an extremely characteristic set of well-defined strata, sharply contrasting in every way with the great limestone zone with which it is packed. It appears to have been let down by faulting among the limestone zone, or to have been tucked in along certain lines and axes of reversed folds and faults—the one process or the other according to the style and energy of the mountain-building forces.

Age uncertain.

There is only one thing certain with regard to its age, namely, that it is younger than the neighbouring limestones; though there are other things more or less probable which will presently be discussed.

The main band or zone of these rocks is very well seen in excellent exposures along the Government cart-road between a point four miles east of the Pyinnyaung and Kalaw. Shortly after getting through the gorge in the Pyinnyaung limestone and crossing a short

thickness of slightly metamorphic pale greenish grey slates and white quartzites with vertical or very high dip, the road turns south-south-east, and follows a long open valley in these purple rocks as far as Nampandet, and then ascends by zigzags to Wetpyu-ye and Kalaw through the same rocks. These purple rocks appear in the section in a sudden manner as if by faulting.

Petrography, lie, etc.

They consist of a very characteristically coloured set of rather soft sandstones and shales, or hardened clays, with occasional conglomerates. Their general colour may best be described as a dark brick-red or chocolate-purple; and as a whole they very greatly resemble many of the Kasauli and Murree beds in North-Western India. This resemblance is so striking that, at the time, I unhesitatingly put them down as of tertiary age, a guess which seemed at first likely to be confirmed by the presence of coal in associated beds which most likely were a southern continuation of the so-described tertiary coal beds examined by Mr. Jones in the vicinity; but, as will be seen later, there is an objection to this view.

As compared with the Pyinnyaung limestone and the associated metamorphic and highly fissile rocks, this purple sandstone group is but moderately disturbed, the dip throughout its complete length being 30° and less, first in towards the metamorphics and then spreading out across the low valley, which, save for the forest, is fairly open and shallow. The slopes facing west are often gentle dip-slopes; those facing east steeper scarps. In some places along this piece of road section, as near Nampandet and Kalaw, the interbedded conglomerates are of considerable coarseness and thickness. They are seen to be an angular or sub-angular conglomerate, the fragments being often very large and composed of harder bits of a similar purple sandstone to those interstratified with them; but a few smaller and more rounded pebbles are of grey limestone. Sometimes along this stretch of country the cuttings expose sandstone of brown-grey or pepper-and-salt colour.

The width of the zone here is about five miles It has an obscure contact with the Thamakan limestone east of Kalaw.

I have met with the same rocks further north at the bottom of the great limestone scarp west of Myinkyardo in the bed of the Panglaung river. The country in between was not examined by me,

but from Mr. Jones' notes [1] about the coal of Palaung and Legaung it seems certain that it occurs in rocks of this zone or in the paler pepper-and-salt sandstones and shales which from evidence further south seem to be united with the purple sandstones into a single stratigraphical and compositional whole.

South of Thamakan, during my route traverse to Loikaw, I again struck more of this purple sandstone zone, which presents a sharp boundary running north-north-west—south-south-east along the west-south-west foot of the prominent limestone ridge near Konni and Pinhmi and a few miles east of Leggia. Here it appears to spread out and include three small ranges parallel to the prominent limestone ridge. The two nearer ones are generally of the purple members of the zone, whilst further west in the neighbourhood of Inwun greyer pepper-and-salt sandstones and soft shales with some promising coal beds make up the section. Such dips as are seen are north-east at angles of 30°, but often higher. As regards the purple sandstones and shales and the pepper-and-salt sandstones and shales with coal, I was certainly impressed with the idea that they were only one continuous series, a single stratigraphical unit; and therefore that the coal as found here would naturally represent the coal found by Mr. Jones at Legaung in what he believed to be tertiary rocks. Hence I was inclined to think the resemblance between the purple rocks and the very similar ones of Kasauli and Murree might reasonably be due to the fact of their being actually of about the same age. (Nests and strings of coaly matter are common in the Murree beds). But now comes the difficulty. On comparing my specimens of these rocks, notably the conglomerate and purple sandstone, with some collected contemporaneously by Messrs. La Touche and Datta east of Thibaw in the northern Shan States, it appears almost certain that they are identical, whilst the latter are certainly the same as Dr. Noetling described from the same locality [2] as "red sandstones of undetermined age" which rest whether conformably or not on the blue limestone, and are in turn overlaid by the recognized late tertiary sandstones and clays with coal beds forming the Lashio coal field.

But Mr. La Touche is inclined to put these with his devonian rocks from some rather obscure fossil evidence. So here we arrive

[1] Records, G. S. I., Vol. XX, Part 4, p. 185.

[2] Records, G. S. I., Vol. XXIV, Part 2, p. 103.

at an *impasse*, where argument is vain. I found no fossils in any of the series except imperfect plant remains in the coal layers; but I think further search there would yield something definite.

The eastern line of junction between the purple sandstone zone and the limestone ridge to the east-north-east begins near Konni and continues as an unwavering line for about 14 or 20 miles and probably further along the route which I followed. Short cross-traverses near this junction at several points showed some remarkable developments of the conglomerate. There are small bands near Leggia and other places, but at Min-ywa and south of it much of the hill-side east of the valley is thickly strewn with blocks of the conglomerate which often becomes so full of limestone pebbles that petrologically it is a limestone conglomerate. Near Min-ywa also there were good examples of interstratification of it with the normal purple sandstone,so that no doubt whatever exists as to its connection with them. It would appear almost as if the much brecciated limestone had become disintegrated under weathering and the fragments flung down as a heterogeneous scree-material among the then forming purple sandstones. South-south-west of Min-ywa on the west side of the valley great hills of what appear to be limestone reveal on visiting them (during a cross-traverse to Tigyit) nothing but huge crags and grotesque masses of this conglomerate, which again on the western slopes overlooking the Tigyit valley are found inter-banded with the purple sandstones. Even more grotesque are the strange pinnacles and "stacks" of this rock as seen some miles further south in the rugged and jungle-covered country east-north-east of Nanpale.

Beyond this point this particular sub-zone was lost sight of during my marches southward, and I do not know whether it dies out or how it disappears in this direction.

Other sub-zones of it appear, however, at more easterly places, but in less marked ways, as, for instance, from east of Salaung as far as the Salween river and along the valley of the Pawn river from Saulôn northwards. There are also a few patches of what may belong to one of these zones on the Government cart-road a few miles west of Möng Pawn, and possibly also in the valley of the Pawn just south of Möng Pawn. Yet, again, it is possible that at one or two places, as at Sanai near Yado in Karenni, there may be representatives of these rocks; but the exposures are too bad for positive identification.

(4) *Sub-recent or Upper Siwalik conglomerates, sands, loams, and clays.*

Approximate age.

The last set of rocks which I have found occurring as sub-zones, or in elongated outcrops among the great limestone zone, show by their general horizontality, by their restriction to the longitudinal valley systems, and by their general appearance of youth that they are either sub-recent or of uppermost siwalik age.

Petrography.

The rocks are sometimes coarse, loosely coherent conglomerates, or hardly solidified pebble beds, with a matrix of sand, the pebbles being very generally hard quartzite, but sometimes limestone. Associated with them are light-coloured sands and pale bluish grey clays and loams, sometimes splashed with red. In a few places a bed or beds of lignite, to which reference will again be made later on in this paper, are found. The whole is either quite horizontal or with only insignificant dips of a few degrees. They spread out and thin away locally along the stretches of level plateau, so that it is often quite arbitrary where their boundaries are placed.

Laterite and other surface rocks.

At many places as near Thamakan their uppermost layers are overlaid by a few feet of laterite which is locally quarried. Along the water-courses which have cut through the conglomerates and sands there is generally a very superficial layer of quite recent clay and loam, flush with the stream banks, and utilized for wet cultivation.

Extension.

The first and most remarkable patch of these sub-recent rocks is found north and south of Thamakan, and lies as a superficial layer over much of the plateau. It gives to the country a soft and rounded appearance, except where the present stream-beds have cut back among it leaving steep-sided nullahs in their wake.

At the latitude of Thamakan these sub-recent rocks are about seven miles wide at their greatest from west to east. North of that they narrow down to a point at Pwehla and south of it come to an uncertain end near Ngon-thon. They are probably some few hundreds of feet in thickness at the most. In general appearance they strongly remind me of the uppermost siwaliks of the Himalayas.

In the Heho and Sinhe valleys the cart-road exposes no certain examples of the conglomerates and sands. At Hopông there is a very thin layer of them; but in the Pawn valley round about Möng Pawn, and apparently stretching up and down the valley for long distances, they appear again in strength making a rounded and flowing valley bottom among which the Pawn and its tributaries run. They even invade the side valleys to the west of Möng Pawn, and so are cut into here and there by the cart-road for a few miles west of that place. The flat valley about Tigyit with its lignite may also contain some of these sub-recent beds beneath the present alluvium.

The same sands and conglomerates are also found west of Nwedaung near Daw-shi, but in small quantities. It is possible that at other places in the valley of the Loikaw river they may also be found.

Between the village of Pyinnyaung and the ridge of limestone to the east there are found a few beds of conglomerate and soft sandstones inclined at a high angle and dipping east. Only a very little is exposed along the road just before getting into the limestone gorge. I cannot be sure that they are of the same age, but they possibly may be.

IV.—ECONOMIC GEOLOGY.

The occurrences of useful minerals, and the economic questions arising therefrom, were naturally matters to which I could devote but little time owing to my rapid movements. But I was able to see some few ores and other minerals, specimens of which Mr. C. E. Browne had been getting together for some time; and later on I had the opportunity of visiting many of the localities in his company.

(*1*) *Coal and Lignite.*

As, in the northern Shan States, the development and utilization of the coal of the Lashio field is an economic question of first magnitude, so also in the southern Shan States is the question of the opening up of some source of mineral fuel for a possible railway there. For the settlement of that question detailed work with that object alone is required. Such rough notes as I have made in my

opinion do no more than show that the matter has certainly not yet been finally disposed of in the negative.

The coal and lignite of parts of the Meiktila District and the southern Shan States formed the subject of a paper in the *Records*[1] by the late Mr. E. J. Jones under the following headings: (2) The Panlaung Coal-field, pages 177-188; (3) Two coal localities in the Shan Hills, pages 188-190; and (4) On lignite occurring near Thigyit near Nyaungwe, pages 190-191. Although the coal of the Panlaung field (supposed to be of tertiary age by Mr. Jones) was good as regards quality, Mr. Jones concluded that it was only found irregularly and in pockets. As regards the two localities in the Shan hills, the coal of the Legaung outcrop has much the same quality as that of the Panlaung field; and, though he does not give any geological data, it seems probable from my own observations to the south and north that it is found among beds of the same zone of formations, namely, my purple sandstone series. The second locality given by Mr. Jones of Ngu, 7—9 miles north-west of Pwehla, I have identified as the place now marked on the one-inch maps as Ngot-ko-Yagyi. The black material is found half-mile east of that place in a band of white quartzitic sandstone among massive limestone of the Heho type, which in places show traces of fossils. It is evidently of quite different age to the other coals of the Panlaung field and of Legaung. As analysed in the Geological Survey Laboratory it only gave 4·62 per cent. of fixed carbon. I found the stuff is locally believed to be plumbago, and a prospecting license has been applied for by a Chinaman. It apparently is a much crushed and sheared carbonaceous or graphitic shale, and is of no value as a fuel, whatever may be its value as "plumbago" to the enterprising Chinaman. It is about 10 feet thick, and dips west at 60° to 70°. A similar material is said by Mr. Browne to be found north-east of Thit-e-bin near Pindaya.

The lignite locality of Thigyit given by Mr. Jones belongs to neither of the two zones of formations above, but belongs to the sub-recent sands and clay filling the Thigyit valley, and as such is no doubt a southern continuation of other similar beds in the sub-recent or upper siwalik sands, etc., of the Thamakan plain, to which I shall again refer presently.

Another coal locality not mentioned by Mr. Jones was visited by

[1] Records, G. S. I., Vol. XX, Part IV, 1887.

me on the information supplied by Mr. Browne. It is just east of Paya-byu (Po-pyu of the 1-inch maps) near Inwun and lies about eight miles south-west by south of Thamakan. The coal occurs in several thin bands among the pepper-and-salt sandstones and shales which I have described above (page 145) as following in apparent conformable sequence and forming a part of my purple sandstone series. The series is dipping at high angles of 70° to 80° north-east by east, and occupies the lower slopes of the 4,886 feet hill (1-inch maps). A fairly continuous section is exposed in the stream-bed for about 600 yards above the valley. There are several layers of carbonaceous shale, three of coal 6 inches thick, one of coal 1½ feet thick, and one of coal 3 feet thick. From observations made in the stream-beds to the north and south of this section, it seems likely that the series is fairly continuous along the strike. The coal appears to be very good but friable. When Mr. Browne first visited this locality the coal was burning in one excavation, and a large concourse of people had assembled declaring it was the fire of hell (nga-ye-mi) escaping. Mr. Browne put out the fire with water, comforted them, and they dispersed to their homes.

I have little doubt but that this coal is a southern continuation of the same beds and the same series as Mr. Jones examined in the Panlaung and Legaung localities.

Outcrops of lignite similar to that of Thigyit occur among the sub-recent sands and clays in a horizontal layer at a point half a mile south-west of Nangon near Pwehla, and also at another place in the same neighbourhood 1¾ mile west-by-south of Nangon. It seems probable that a more or less continuous layer of it exists among these superficial rocks; but it does not seem to be very pure or very thick.

(2) *Copper.*

Copper ore in the form of antimonial tetrahedrite (sulphate of copper and antimony) with azurite and green carbonate and with small quantities of arsenic, iron, zinc, silver and lead,[1] occurs at a number of isolated places round about Yataung Hill, which is four miles north-east by north of Myinkyardo. Some prospecting licenses have been applied for. At one place, Ganaingya, 1½ miles due south of Yataung Hill, I saw surface working going on, having

[1] As determined in the Geological Survey Laboratory.

recently been started by Ganapatty Pillay of Moulmein, the ore being as described above. The ore occurs in limestone of the Heho type dipping west by north 30°. It is in thin veins running with the bedding on the east side of the hill. I was informed that more of this ore exists also at Mene-Taung and A-le-Chaung (localities a few miles away).

Copper ore is also said to be found four miles west-north-west of Magwe near Kalaw and also in the stream-beds running to Kwe-ma-sa, south of Nampandet.

(3) *Gold.*

I saw no gold *in situ* during my tour, but it is said to occur about 4½ to 5 miles west-north-west of Magwe (near Kalaw) in the Thamakan State The occurrence is in a quartz vein. Gold is also said to be washed for in the stream-bed north and north-west of the same place.

Gold is also said to be found in the Baw State in the hills between the Zawgyi river and the Myitnge river. It is in the form of dendritic crystals and flakes in cavities along with quartz crystals in quartz rock or gneiss. The hill is about 3,000 feet high and lies about ten miles north-east of Myogyi town.

(4) *Lead.*

The argentiferous galena of Bawzaing and the native methods of smelting and cupelling it have been fully described by Mr. Jones in his paper above cited, and need not be detailed again here. Several mines round about are being worked now by Chinese firms, the chief localities being :—

1¾ mile east-south-east of Bawzaing.

2½ miles north-by-east of Bawzaing (the Siszet mine), poorer ore, but containing much more silver.

Kyauk-ku-lcywa State, in the hills (latitude 20° 55′, longitude 96° 40′) away from all villages. It is worked by the chief of the Pwehla State.

The following mines are not worked now :—

1½ mile east-south-east of A-le-Chaung and 4½ miles north of Myinkyardo.

Pakin, about 1½ mile north-north-west of Bawzaing.

Meiktila district near Pyinnyaung 29 miles on the cart-road from Thazi to Taunggyi.

(5) *Pyrites.*

Pyrites is dug for the manufacture of sulphur at Yebok in the Pwehla State, and also at places in the Bawzaing State.

(6) *Saltpetre.*

Saltpetre is manufactured at Nam-tok from the nitrate-impregnated soil gathered beneath the surface of the stalagmitic floors of caverns at the foot of the limestone hills north of Nam-tok.

(7) *Tin.*

Tin ore (found by Mr. Holland to be cassiterite mixed with a certain amount of wolfram), is gathered at the villages of Mawchi, Lekhalu, and Re-ho-hku in the Bawlake State, Karenni. As described by Mr. W. G. Wooster, Assistant Political Officer of Karenni, the ore is washed out of the soil by water gathered during the rains in tanks above. I was not able to include a journey to these places in my tour. Mr. Holland reports of the specimens sent in to the Geological Survey Office that both the ore and purified metal are of excellent quality.

(8) *Tourmaline (green).*

Some beautiful transparent dark emerald-green crystals of the above were shown me by Mr. Hildebrand at Thamakan. They had come from a locality known as the 'green stone tract' near Namon in Karenni, on the west bank of the Salween river about thirteen miles north of Ywathit. They had been locally and wrongly identified as green augite (diopside), but I believe were supposed by some to be true emeralds. To make certain I despatched a packet at Mr. Hildebrand's request to the Geological Survey Office for determination, with the result that they were pronounced to be green tourmaline as I supposed. Later on I visited the locality with Mr. Wooster and found a small settlement of miners at work digging and washing for them. The stones are very beautiful in appearance, all being bounded by natural and brilliant crystal faces chiefly of the rhombohedron and prism. In size they vary from that of a pea to that of a small bean. The surface soil of the country, a brown sandy clay

with pisolitic ferruginous concretions, on the hill-sides among the blocks of crystalline limestone, is everywhere to the north and west of the little mining village dug into little holes and trenches. The sandy material is taken out, gone over by hand, and finally washed in the stream-bed. From the unrolled appearance of the stones I concluded that their matrix must be somewhere near in the crystalline limestone, and further search showed this to be the case. I was able to bring away pieces of a handsome white marble with the green tourmaline embedded in them. Packets of 10 or 12 rather large stones were shown me which the possessors declared would fetch R300 to R500 in Rangoon. But this seems to me to be a fictitious value probably due to their being at present successfully passed off as true emeralds. Their absolute market value will doubtless in time descend to something much more modest than this ; but they will always have a certain intrinsic worth as pretty stones suitable for ornaments and setting in rings, etc.

Preliminary Report *on the* Geology *of the* Ganjam District, *by* F. H. SMITH, A.R.C.S., *Deputy Superintendent, Geological Survey of India.*

The Ganjam District has practically never been geologically surveyed. A small tract to the extreme south, round Chicacole and Parlakimedi has been mapped by Mr. F. Fedden, and one or two notes have been recorded as to the prevalence of granitic rocks in the Berhampore neighbourhood; otherwise the country has remained unexamined. During the field season of 1899-1900 I traversed some 7,500 square miles, comprising the whole of the Ganjam District with the exception of the small area above mentioned.

Topography.

The Ganjam District may be divided, roughly, into two equal parts; the eastern half, or coastal region, consists of a plain, almost entirely under rice cultivation, thickly dotted with isolated rocky hills and small ranges up to 2,000 feet in height. The western half, known politically as the "Agency tracts," is an area of raised hilly country from 1,500 to 5,000 feet in altitude. The hills are the Ganjam Malias, which form the Ganjam section of the Eastern Ghâts. Travelling amongst them is restricted entirely to a few Government roads; and they are very malarious, fever attacking with special virulence natives of other parts of India.

General geology.

The whole of the Ganjam District is composed of crystalline rocks which may be divided into two main groups; (1) A complex mass of crystalline igneous rocks, varying considerably in composition, texture, and foliation; and (2) a series of bands of more or less crystalline schists, which are crushed and folded into the igneous rocks. The first group covers by far the greater area of the two.

No unaltered sedimentary rocks are met with, but considerable areas near the coast are covered with laterite, and amongst the Malias certain patches of hills are capped by it.

CRYSTALLINE SCHISTS.

The schist evidently represents a more or less metamorphosed series of ancient sedimentary rocks, originally consisting of ferruginous, shaly sands and grits, with bands of impure limestone. In places the schist passes gradually into these sandy and gritty forms, but usually the latter have been entirely altered, chiefly by dynamometamorphism, into true crystalline rocks, of which the commonest form is a quartz-garnet schist always rich in sillimanite.

The rock varies greatly in its degree of alteration, and it shows every gradation from an earthy, decomposed quartz-hæmatite schist to an extremely compact, pure quartz, and garnetiferous rock. Besides sillimanite, various accessory minerals are of constant occurrence, of which the chief are felspar, mica, graphite, epidote, and rutile.

Mineral limestone.

The original calcareous beds are now represented by several interesting bands of highly crystalline impure marble amongst the schists. This is always

rich in accessory minerals, which are often in such abundance that they almost entirely replace the calcite. About two miles to the north-north-west of Purshottapur two bands of this rock, varying from a fine-grained mineral limestone to a handsome coarse-grained marble, occur, folded amongst the quartz-garnet schists. The rock is essentially a crystalline limestone containing much yellow-red garnet and pale-green diopside ; microscopic examination reveals the presence also of quartz, felspar, tremolite, apatite, epidote, sphene, and rare tourmaline.

A band of a very similar rock occurs under the same conditions in the hill-shoulder above Worradamooli, near Kallikota. This is a fine-grained dioritic-looking rock consisting of quartz, felspar, diopside, scapolite, sphene, and apatite.

Occasional exposures of similar diopside-bearing rock are seen amongst the Malias, always occurring as bands of slightly varying composition associated with the quartz-garnet schist.

Spinel-bearing rock.

Another form of the schistose rock occurs in the vicinity of intrusions of coarse pegmatite, and this is evidently due to some extent to contact action. In the Mussellkonda neighbourhood veins of micaceous pegmatite are found, near which dark ferruginous bands are seen in the schist. They consist of a granular rock composed of garnet, magnetite, spinel, augite, plagioclase, enstatite, quartz, and apatite. A similar rock is seen in the boundary range, six miles north of Kallikota. This is composed chiefly of garnet and magnetite—the latter passing imperceptibly into dark-green spinel, which is speckled with minute magnetite grains—with scattered grains of quartz and hypersthene.

Mode of occurrence.

The igneous rocks which form the main groundmass of the whole district are frequently seen to be extremely crushed and foliated, and much of this crushing has taken place since the solidification of the rock. The folding that then occurred evidently enveloped large masses of the overlying sedimentary rocks, now only represented by the bands of schist, which remain amongst the granites and gneisses. The subsequent metamorphism undergone by the folded bands appears to have been almost entirely due to pressure and only in a very small degree to contact action. Intrusive granite is found in one or two localities, notably near Russelkonda, but as a rule igneous intrusions

of any kind are extremely rare, and in the great majority of the schistose bands they are never seen.

The bands of mineral limestone appear to form subsidiary layers amongst the ordinary schists, and to have been originated at the same time, and by the same agency as they were. The marbles are very similar in appearance and composition to the ruby-bearing rocks of Burma; but they have been carefully searched both in the field and under the microscope without any trace of ruby, sapphire, or ordinary corundum being discovered.

The junction between the schists and the surrounding crystallines is very seldom seen. The hills are always covered with thick jungle, and the schists weather very readily into a red ferruginous soil, which effectually conceals their boundaries. Occasionally in the outlying rocky hills the two series of rocks are found in contact, and then the junction is seen to be one of gradual passage. The schist becomes more crystalline towards the edges, passing into a true gneiss, which soon becomes indistinguishable from the surrounding granite. The two rocks have apparently been crushed together along the boundary, and passage bands have thus been formed.

Distribution.

There is a conspicuous difference in appearance between the hills composed of massive crystalline rock, and those composed of schist, and the distribution of the two series can be easily seen at a distance. The igneous rocks, especially the coarser granites and gneisses, form bold rocky hills strewn with boulders, often capped by great domes of bare exfoliating rock, or precipitous castellated peaks. The schists weather into smooth, red, soil-covered slopes, overgrown with low bushes. The rocky hills are frequently seen to be so seamed and banded with the red schist-bands that it is impossible to map the two groups accurately.

The foliation strike of the schists is most inconstant, the bands running in all directions. In the eastern part of the district the dip of the foliation planes is often low, and the strike varies widely; but to the north and west, in the hill tracts, the foliation is practically always vertical, here the variation in strike is usually limited, ranging between north to south, and north-north-west to south-south-east. Schistose bands are found scattered impartially over the whole of the Ganjam District, and locally they occupy

fairly large areas. In the southern half of the Malia Hill Tracts the schist is somewhat infrequent. Over the coastal region the distribution is very even, but one large patch of schists occurs between Ganjam and Kallikota, stretching from the coast for some twenty miles westwards inland. The northern end of the Malias also contains extensive bands of schist. The largest of these, covers the extreme western prominence of the Ganjam District, to the west of Tumriband and Kotgar. The latter area is interesting on account of the curious formation of the hill-ranges. A hill tract, some fifteen miles in length by ten in width, and rising to 4,000 feet in height, is entirely composed of quartz garnet sillimanite schists, with vertical foliation and north to south strike. The summits of all the ridges are formed of the remains of a once continuous, horizontal laterite cap, up to about 200 feet in thickness. The view from the top of any of these ridges is curious, every hill-range is approximately of the same height, and the top is perfectly level for long distances. The country was evidently once covered by a laterite plateau, which has been carved and gradually cut out by denudation, leaving the tops of the ridges alone of laterite, while the flanks and valleys are of schist. I have found hills of identically the same description eighty miles to the north-west in the Sambalpur District, in the Central Provinces, notably the Gandamardan or Narsingnath range in the Borasamar zamindari. There a bold range, over 3,000 feet in height, of exactly similar rock, is capped by a horizontal plateau of laterite, from which the sacred stream of Narsingnath springs. Mr. V. Ball [1] also mentions several similar ranges, with flat laterite caps, which occur in the intervening Kalabandi State.

Age.

There is no evidence in Ganjam by which to determine the age of the schists. They have a general resemblance to the rocks of the older transition series, but none of the typical Dharwar forms are found amongst them. There is no doubt that they are identical with the rocks of the Gandamardan Range, and the latter have the advantage of occurring within a few miles of beds of Cuddapah, or lowest Vindhyan age. The latter are shales and quartzitic sandstones, which are quite unaltered. So it seems safe to assume that the quartz-garnet schists are of considerably greater age than the Cuddapahs.

[1] Records, G. S. I., Vol. X, Part 4, p. 169.

CRYSTALLINE IGNEOUS ROCKS.

The main foundation of the whole of the Ganjam District is a somewhat complex mass of crystalline rocks of igneous origin. By far the greater part of this mass consists of garnetiferous granites or granulites, but amongst them are found various bands and dykes, usually of more basic character and containing rhombic pyroxene, of which the following are the chief: pegmatite, biotite gneiss, hypersthene granulite, varying from acid to almost basic forms, and representing the charnockite series; augite, mica, and hornblende diorites.

Amongst the rocky hills, covered with soil and thick vegetation, it is practically impossible to make out the relationship of the different rocks to one another. But it may be generally stated that pegmatite, and most of the diorites are younger intrusive rocks. Some few of the diorites, and the hypersthene granulites, are older than these, and of the same age, or perhaps a little younger than the main granites, from which the biotite gneiss has been locally derived.

Garnetiferous granitic rocks.

The most common form of the granite is a coarse-grained rock chiefly composed of quartz, with plagioclase felspar, garnet, and usually more or less biotite. The composition does not vary greatly, and then only as regards the amount of ferro-magnesian constituents. The texture and foliation vary widely. The finer-grained varieties appear to weather the more easily and they seldom give rise to bold features of the country. The coarse rock forms the great boulders and broken scarps which are so common throughout the granite hills, and its texture is frequently very coarsely porphyritic, containing crystals of felsar up to 6 and 8 inches in length. The coarse rock is also conspicuous when strongly folded, the porphyritic crystals being pressed out into flat patches of broken fragments. The biotite gneiss is a crushed form of the non-garnetiferous granite.

Granulite.

A very common form of rock is fine, or medium-grained and strongly-foliated, containing dark layers of garnet amongst white layers of quartz and felspar. This represents the typical form of "granulite," and it passes insensible into the charnockite series by the inclusion of rhombic pyroxene,

usually in the form of hypersthene. In the field it is often impossible to tell from the appearance of the rock whether it is hypersthene-bearing or not, and there is every gradation between the ordinary granulites and the true, almost basic charnockites.

Hypersthene granulite.

The hypersthene granulites are seldom seen to be banded or foliated in the field, but under the microscope they are nearly always seen to be much crushed, the constituent grains often being almost mylonitic, and showing evidence of great strain.

The more acid hypersthene granulites have a very characteristic appearance. They are of a general greyish colour, but if looked at closely, the rock is seen to be coloured bluish by milky quartz and pink, or red by garnets scattered through it. Garnet seems to be a constant constituent throughout the acid forms, but it decreases gradually and dies out entirely from the more basic rock. The former generally consist of quartz, plagioclase-felspar, garnet, hypersthene, biotite, and magnetite.

The acid forms pass gradually by the inclusion of more and more rhombic pyroxene, into a dark lustrous rock, of greenish or brownish black colour and more or less basic composition, though it still contains a considerable amount of free quartz. The constituents are generally plagioclase, quartz, hypersthene with enstatite and augite—biotite, apatite, and occasionally epidote.

The hypersthene granulites are so intimately associated with the surrounding granites that it is very difficult to tell what is the relationship between the two. The former appear generally to be banded in amongst the granites, and to have shared to varying extents in their crushing. The acid hypersthene-bearing rocks would suggest the mixture of the original magmas in a more or less molten state; while the more definite bands of basic charnockite were probably intruded into the granite after the solidification of the latter. But it seems probable that the age of the two is very much the same. Many of the rocks which appear to be coarse garnetiferous granites, prove to contain pyroxene, and they are sometimes seen to be intrusive. An interesting exposure of this kind occurs about a mile to the north-east of Bigupudi bungalow. A low dome of massive rock is found to be composed of extremely coarse, porphyritic pyroxene granite, containing felspars up to 1 foot in length. At the sides and end of the dome, the rock becomes more fine-grained, with small

crushed porphyritic felspars; whilst at the edge the rock is extremely fine-grained and is seen to be composed of a mylonitic ground-mass of plagioclase and quartz with crystals of enstatite, magnetite, and epidote. The coarse rock appears to have been an ancient intrusive mass, which has withstood the crushing that has gone on around it.

Fine-grained augitic rock.

There is another form of more or less basic augite-bearing rock, which seems to be quite distinct from the charnockite series. It is always very fine-grained and it appears in two forms, occasionally as an ordinary intrusive dyke, but more frequently crushed and mixed into the coarse granitic rock. In the latter case it is impossible to tell which of the two is the older, they are so intimately interbanded and interlaced, that each in turn appears to be intrusive upon the other. This rock is chiefly developed in the neighbourhood of Aska. It occurs throughout the hill mass a few miles to the south, interbanded and mixed with coarse granite, and again eastwards round Boirani, in a slightly modified form, in the form of dykes amongst highly-crushed coarse gneiss. The rock to the south of Aska is found to be a typical 'Kersantite,' being a fine-grained granular diorite, composed of plagioclase, augite, biotite, quartz, and magnetite. As might be expected from the mode of its occurrence, it shews signs of strong crushing. The dyke rocks of Boirani have a slightly different composition,—plagioclase, quartz, enstatite, magnetite, and epidote—but they are very similar in appearance to the Aska Kersantite, and they have undergone subsequent pressure to an extreme degree, the quartz and felspar being crushed to a mylonitic mass. Similar rock is occasionally found amongst the Malias, banded with the granites. It is quite distinct from the more recent dykes, which are not crushed, and it evidently represents an older intrusive rock which has subsequently been folded and crushed amongst the surrounding granitic mass.

Trap-dykes.

Unaltered trap-dykes are very rare throughout the whole district. A few of small extent are seen amongst the Malias. These are of fresh dioritic rock, and they are evidently of comparatively recent age. The dyke-rock is a hornblende-diorite consisting of somewhat granular quartz, plagioclase, hornblende, and some rhombic pyroxene.

In one or two places warm sulphurous springs rise amongst the crystalline mass. The best-known of these is the 'Taptapani' which rises in the hills, about 8 miles to the north-west of Poramari. It is a small spring of slightly sulphurous water, about 115°F. in temperature, in which a constant stream of bubbles of sulphuretted hydrogen rises. It is situated in the midst of massive granulites, and as in the other cases, there is no evidence to determine its origin.

Hot springs.

The mass of the crystalline igneous rock, granites and granulites, is evidently of great age. It presumably formed the foundation, whereon were laid down the sedimentary beds, from which the schistose bands have been formed, a supposition which gives the crystalline igneous rocks an age considerably greater than that of the schist.

Age of crystallines.

The foliation of the igneous rocks, like that of the schists, is very variable in direction, and the folding of the rocks appears to have been due to local causes rather than to any one great and wide-spread disturbance. It would seem that at a remote time, previous to, and during the 'Transition' period the igneous rocks were subjected to strong local disturbances, which resulted in the crushing and banding of the hypersthene granulites, and of the older intrusive rocks, and also in the folding and inclusion of bands of the overlying sedimentary rocks, subsequently altered more or less completely into quartz-garnet schists. Since these disturbed times the country has been at rest, and the few more recent dykes of intrusive rock, which have succeeded in reaching the surface, are still fresh and unaltered in every way.

A good deal of the country near the coast is covered with irregular deposits of laterite, which weathers into a somewhat barren red soil. The laterite is of no great thickness, being often only a shell of a few feet, underneath which decomposed and weathered rock is often visible. The latter appears to be invariably the quartz-garnet schist, from which the laterite is directly derived. The coarse granitic rocks are never seen to have any connection with the patches of laterite.

Laterite.

Besides this low-level laterite, a similar vesicular, ferruginous clay is found, capping the western extremity of the Ganjam Malias at a height of about 3,500 feet. This high-level laterite cap has been already referred to as exactly similar, and overlying

similar rock, to that of the Gandamaidan range in Sambalpur, and like the latter it contains the chief water-supply of the surrounding country, springs arising all along the lower edge of the laterite. This cap seems to be the eastern extension of the high-level laterite which occurs throughout peninsular India, but it is noticeable that its occurrence is limited to the areas occupied by the quartz-garnet-schist, which alone of the Ganjam rocks seems to pass directly, by decomposition and concentration of the iron, into laterite.

MINERALS.

Ganjam has often been credited with the possession of valuable mineral resources. Sapphires and gold have been mentioned as occurring in the district, and the occurrence of workable deposits of manganese in Vizagapatam to the south has led to the hope that the same mineral might be found in Ganjam. Unfortunately the examination of the country shows that valuable minerals, with the possible exception of mica, are not to be found in the Ganjam District.

In one field season it is, of course, impossible to carry out detailed prospecting over so large an area, but during my tour no minerals of economic value, except mica, have come under my notice, nor could I obtain any information of their existence in the district, from the local authorities or from the villagers themselves.

Manganese.

As far as I could discover there are no traces of manganese in Ganjam.

Iron.

Amongst the Malias there are a few native iron-workers, but they usually procure their iron already melted. Smelters are only found in one or two localities where they procure a soft earthy hæmatitic ore from the laterite.

Graphite.

Graphite has been mentioned as forming a rich graphite-schist on the east coast of India. It does occur in most of the quartz garnet-schists, but only as minute specks scattered through the rock, visible as brilliant silvery grains. The total amount of graphite is quite insignificant.

Gold.

One of the chief objects of my work in Ganjam was the discovery of gold, but I was unsuccessful in finding any gold-bearing reefs in the district.

Quartz reefs are almost entirely absent throughout the whole of the igneous crystalline area. Occasional small veins of white quartz

are met with, but no trace of gold is to be found in them. A more hopeful-looking rock is seen in one or two places amongst the schists. It is an opaque or iron-stained quartzose rock, forming a band amongst the garnetiferous schist, but it also gives no trace of gold on testing, and no visible gold is obtained when the rock is crushed and washed.

I was informed that gold-washing was carried on in the streams round the foot of Mahendragiri, but on my arrival there the villagers and the local authorities knew nothing of it. Near the summit of Mahendragiri, I found one grain of gold while washing the sand of a small stream. But no more gold could be found, and no quartz reef was to be seen in the neighbourhood.

Amongst the Maliaś the hill tribesmen do not attempt to wash for gold in the streams and there appears to be no gold in them.

Sapphire.

Sapphires have been reported as occurring in the Ganjam District; in fact, a packet of small stones, described as coming from the Mahendragiri Mountain, were sent to the Office of the Geological Survey in Calcutta for determination. They were found to be sapphires, of a fine blue colour, transparent to translucent, and of considerable value. I spent a day or two on the summit of Mahendragiri, unsuccessfully searching for such gems, and I then learned the true history of the stones, some of which had found their way to Calcutta. Mahendragiri is almost the highest hill in Ganjam, 4,923 feet in height, and is well known as having several fine temples built on its summit, as well as many small shrines and monoliths. This is probably sufficient to connect the hill in the popular mind with visions of buried treasure. It appears that some fifteen years ago, a trader, described as a 'Kabul merchant,' spent some days on the summit of Mahendragiri digging in the mounds, on which the small monoliths generally stand. The earth extracted was sifted, and the trader brought down some fine gravel with him, from which about sixty sapphires were picked out. These were eventually cut and polished in Madras, and pronounced valuable. The trader hoped for a reward from the Mandasa zamindari in which Mahendragiri is situated, but whether he took the stones up with him, or whether he had previously obtained information as to their hiding-place seems uncertain.

The mass of Mahendragiri is composed of garnetiferous granulite which passes into a very coarse, porphyritic garnet-granite near the

summit, whilst the actual ridge consists of a band of hypersthene granulite. There is no trace of corundum, or sapphire, to be seen throughout these rocks, nor could I find any gems in the sands of the small streams which traverse the hillsides. I carefully washed the earth which remained in the mounds, but with no better results, so it would appear that all the sapphires had been successfully extracted.

As has been already mentioned the mineral limestone of Purshottapur does not yield any trace of ruby or sapphire.

Mica.

The only mineral in Ganjam of possible value appears to be mica, which has been known for some time to occur in the neighbourhood of Russellkonda. It has been extracted in small quantities, from time to time, by native physicians, who value it highly as a general medicine after it has been burnt and finely powdered.

The chief locality where mica is found lies a few miles to the south-west of Russellkonda, in a strip of jungle-covered country between the Russellkonda-Aska road and the hills to the west. The mica appears at the surface as broken and frayed flakes amongst a loose gravel. These exposures are fairly frequent, and there is no doubt that many new outcrops might be discovered if the country were systematically searched.

The mica is a constituent of a coarse, more or less micaceous pegmatite, which occurs in i regular intrusive veins amongst the surrounding rocks. The latter are usually fine-grained granulites, but in one or two instances the pegmatite intrudes into quartz garnet schist. The composition of the pegmatite is capricious and varies very rapidly, and a vein which is highly micaceous at one point is frequently found to be composed of quartz and felspar only, with occasional tourmaline, at a few yards' distance. I selected the three richest outcrops of mica, on which to sink pits, in order to determine the quantity and quality of the mica in the fresh rock below, and these three pits were sunk at the villages of Goradandi, Bodiamba and Jillundi.

The results are not very encouraging as regards these three particular exposures, though mica of fair size was discovered. But the fact remains that this country is seamed by veins of coarse micaceous pegmatite, which, if only the right locality could be found, is

quite likely to yield valuable mica, as it does further to the south in Nellore.

Goradandi.

The Goradandi pit was sunk in a dyke of coarse pegmatite, 30 feet in width, running north and east. The dyke can be roughly traced on the surface for a distance of 100 yards, but it is only highly micaceous in one place. Here, in a coarse granite, somewhat decomposed and kaolinised, mica-crystals are found up to 3 inches in diameter. The mica is broken and dirty, and it contains frequent small quartz-crystals. The quality does not improve below, and the lateral extent of the micaceous rock is only a few yards.

Bodiamba.

At Bodiamba a band of highly micaceous gravel was seen, in which a trench was dug, but on reaching the underlying pegmatite, it was found to be entirely unproductive.

Jillundi.

Near Jillundi on the Russelkonda-Aska road mica had been extracted occasionally within the last few years. The pegmatite dyke cannot be traced at all on the surface, and mica-bearing surface gravel was the only indication of its presence. This pit was the most successful of the three. At a depth of from 3 to 6 feet a considerable amount of mica was found in fairly solid crystals or "books" of irregular shape and up to 5 inches in diameter. The mica is somewhat frayed and earthy, from the results of surface action on the rock. Below 6 feet however the rock rapidly loses its mica, and at 8 feet in depth it passes into almost pure quartz, with rare crystals of felspar.

The mica extracted from the three pits has practically no market-value. The area of the plates is not sufficient—it is barely possible to cut rectangles 3 × 2 inches from the largest crystals, and this size, if pure and clean, has only a maximum value of 2 annas per pound, and the mica is usually dirty and very frequently penetrated by quartz crystals. The micaceous rock, too, in all these cases is very limited in extent. On the other hand it is quite possible, that in this neighbourhood localities may be found where the micaceous rock is developed on a large scale,—both as regards its mass and the size of the included mica-crystals.

Coarse mica-tourmaline-granite is also found among the hills about three miles to the north-east of Russellkonda, but so far no mica-crystals of more than 2 inches in diameter have been seen in it.

A Geological Sketch *of the* Central portion *of* Jêypore Zamindari, Vizagapatam District, *by* W. L. WALKER, M.A., PH.D., *Geological Survey of India.*

I.—INTRODUCTION.

The country which is the subject of the present geological sketch constitutes the central portion of Jeypore Zamindari, and corresponds to that portion of Vizagapatam District which is contained in the north-east quarter of Atlas Sheet No. 93. The area of the country surveyed is about 2,500 square miles. Arriving in Jeypore about 20th November 1899, I carried on explorations till about 20th March 1900, when I returned to Calcutta *viâ* Vizianagram. There are very few good roads, or even poor ones, but coolies are easily obtained for transport in this particular region, though in the unsurveyed country to the south neither coolies nor carts can be used, and elephant transport is essential.

Position of area surveyed.

The eastern part of the country, reported upon as part of the Eastern Ghâts, forms part of a great plateau of about 3,000 feet altitude; to the west it falls gradually from 2,000 feet in the Kotpad region, to about 700 feet south near Salmi. Two rivers rise in the hills to the east, the Indrabati flowing westward into the Bastar State and the Kolab which, after a circuitous course, empties into the Godavari. The eastern plateau consists of low undulating brownish hills, either quite devoid of tree vegetation, or at most poorly wooded in the intervening valleys, while the north-western part constitutes an almost level plain of valuable arable land. Most of the south-western part, from Ramagiri and Modpodor southward, is well wooded with forest, of sâl and occasionally teak, which, in the future, if carefully preserved, will prove to be of immense value. Rock outcrops in the hilly country are very frequent and large, while in the lower country to the west, alluvial deposits and vigorous forest growth conceal the rock formations over large areas.

Topography.

Geologically four rock groups are readily distinguished :—

I.—The greater part of the region west of the hill range is composed of crystalline schists—biotite and hornblende gneisses—and schists—potstone and quartzites.

II.—The hilly country forming the eastern part of the country surveyed, is made up of rocks which can best be referred to as hypersthene granites, generally garnetiferous and at times showing such marked parallelism, as to be regarded as gneissoid granites, if not simply gneisses.

Rock groups.

III.—The comparatively level country in the vicinity of Kotpad is deeply covered with clay and sand, so that outcrops are very rare, but those that occur, indicate a rock formation of old non-fossiliferous sediments, probably Cuddapah in age. A narrow strip of similar rocks extends south along the Bastar-Jeypore boundary as far as the Tulsi Hills.

IV.—A few isolated outcrops of diabase have been observed, less altered forms near Jeypore, and again quite altered ones near Ramagiri.

This region had never been geologically examined before, and when the adjoining unsurveyed country has been surveyed, a full geological report may be possible, the present sketch being only preliminary. Reference to the geologically coloured copy of the north-eastern quarter of Atlas Sheet No. 93, which accompanies this report [1] will make clear all geological and topographical references contained in the present sketch.

II.—CRYSTALLINE SCHISIS.

These rocks occupy the region between the 3,000 feet plateau, and the Bastar boundary, except for a small patch of Cuddapahs on the extreme north-west and west of the country surveyed.

Origin of crystalline schists.

Professor Rosenbusch recently boldly divided crystalline schists into two classes. Those which in chemical and mineralogical composition are closely related to igneous rocks he designates with the prefix *ortho*, and considers as probably metamorphosed igneous rocks. Other schists, however, are closely related chemically to sedimentary rocks, and these he regards as metamorphosed sedimentary rocks, and he distinguishes them as *para*-schists. We thus have *ortho*-gneisses and *para*-gneisses according as there is reason to believe that the rocks in question are metamorphosed, igneous or sedimentary rocks.

[1] Not yet published (Dir.).

Ortho-gneisses.

In a general way the schists north of Ramagiri and Guma are of the ortho group, being somewhat coarse granitoid gneisses which in hand specimens would pass for granites. Both biotite and hornblende varieties occur, though the former is the commoner rock. Where not too well foliated, the felspars are large with a porphyritic tendency. The general strike is north-west. The best exposures occur north of Ramagiri, where the rock is so granitoid, that I was at first inclined to look upon it as granite. In the vicinity of Guma and Bagderi this rock is also abundant. (Specimens $\frac{14}{495}$, $\frac{14}{498}$, $\frac{14}{499}$ and $\frac{14}{500}$.)[1]

Potstone.

At numerous points to the west and south-west of Jeypore, outcrops of a coarse grey potstone have been observed. Near Noaput and Outagaon some three miles from Jeypore small quarries have been opened and the potstone hewn for building stone and carved into idols. It is again seen between Bipariguda and Modpodor on the Ramagiri road. The largest masses, however, are found on the Malkongiri road, four or five miles beyond Kolar bungalow. In this last occurrence the rock alternates with quartzites and well-foliated biotite gneisses which have a well-defined north-west strike, dipping from 45°-60° to south-west. The potstone, however, is fairly massive in all the occurrences examined (specimens $\frac{14}{496}$ and $\frac{14}{497}$).

Para-schists.

The schists south of a line from Kolar to Ramagiri belong to the *para* class. Biotite gneisses, very poor in felspar, occur over the country from Kolar to Pangam and northward to Tetulgama and Ramagiri. These gneisses are well foliated and strike north-west, though the dip varies. To a very small extent possibly as crushed synclinals these rocks occur as bands in the ortho-gneisses already described. Hornblende gneiss, pistasitic quartzite, white quartzite, quartz magnetite schist and greyish slaty mica schists occur as subordinate members of the para group of schists.

III.—Hypersthene Granites.

Hypersthene rocks.

The hilly plateau country previously referred to forms the eastern part of the country geologically surveyed. The hypersthene series is bounded on the west

[1] Reference to register numbers of the petrological collection of the Geological Museum, Calcutta.

by the crystalline schists, the irregular line of contact passing about north-north-east through Jeypore. The rocks composing these hills are characterized by hyperstbene, generally accompanied by common red garnet, and vary in acidity from norites with a specific gravity of 3·07 (specimen $\frac{14}{400}$) to granites with a specific gravity of about 2·70. When fresh they are of a bluish to greyish black colour. Very coarse and even porphyritic forms occur, but the even-grained dark aphanitic rock is more typical.

Previous nomenclature.

These rocks occur commonly in Peninsula India, where they have been studied by many geologists of this department. On account of their forming most of the hill masses of the Peninsula, Dr. King, late Director of the Geological Survey of India, called them mountain gneiss. More recently Mr. T. H. Holland has studied them, and in a memoir, now in press, proposes to call them *Charnockites* in honour of the founder of Calcutta. Lehmann and others have given us very full descriptions of similar rocks from the granulite formation of Saxony, where on account of their close relations with the granulites, they have been variously called, diallage granulites, augite granulites, trap granulites and pyroxene granulites. The last name is now generally accepted for the Saxon occurrences.

I prefer to use a nomenclature having reference to the mineralogical compositions, so that the names indicate the mineralogical composition and general nature of the rocks.

Position of Jeypore Occurrence.

In the Hill Tracts of Vizagapatam District a great elliptical mass of these rocks appears to make up the most of the Eastern Ghâts. The longer axis of the ellipse has a north-north-easterly direction, while the area is probably four or five thousand square miles. The minor axis extends from Jeypore to within five miles of Salur, a distance of about sixty miles. The comparatively small part of this great mass, geologically examined during the past field season, constitutes only the central portion of the north-western half of the ellipse.

Structure.

Both granitoid and gneissoid forms occur, though it is very probable that both forms are essentially the same from a genetical point of view. The gneissoid structure appears to have been induced by a pressure, acting at right angles to the major axis of the elliptical mass, and to the direction

of the usually imperfect banding or foliation. When examined under the microscope in polarized light, thin sections show that the constituent grains of the minerals of the gneissoid varieties of these rocks are so very free from pressure phenomena, that it is almost certain that the foliation was induced at a time when the temperature of the rock was sufficiently high for it to be fairly plastic.

Hypersthene syenites.

The commonest variety of these rocks is a heavy bluish black massive form which the microscope shows to be granitoid in structure, and composed chiefly of anhedra of hypersthene, and almost equal parts of twinned and untwinned felspars. Next in importance are reddish garnets often idiomorphic, green hornblende, pale greenish augite, quartz biotite, and iron ores, but never sphene. Except the idiomorphic garnets, the other minerals are usually xenomorphic. Gneissoid varieties occur. The specific gravity varies from 2·77 to 3·00. This form may be referred to as hypersthene syenite. (Specimens $\frac{14}{443}$ and $\frac{14}{448}$).

Norite.

A more basic variety in which hypersthene and plagioclose are the chief minerals, and garnet orthoclase, greenish augite, iron ores, and a little hornblende or biotite the accessories, resembles so very closely the ordinary norite, that it requires no special name. In specific gravity it varies from 3·00 to 3·14. (Specimens $\frac{14}{445}$, $\frac{14}{447}$ and $\frac{14}{450}$).

Hypersthene granite.

More acid varieties in which orthoclase and quartz predominate, and hypersthene and the accessories are less abundant, may be regarded as hypersthene granites. These granites in the field appear to pass gradually into varieties free from hypersthene, as is seen in the case of the rocks composing several of the hills between Goserla and Kolar (specimen $\frac{14}{453}$). Here coarse and even porphyritic forms are much more frequent than in the case of the more basic varieties. Gneissoid rocks of this mineralogical composition occur.

Diopside rocks.

In several places, associated with the hypersthene rocks above described, hypersthene diopside varieties were observed. In some a green spinel is present (specimen $\frac{14}{446}$), while in others plagioclase and sphene are particularly prominent. (Specimens $\frac{14}{459}$, $\frac{14}{460}$, $\frac{14}{461}$, $\frac{14}{462}$, $\frac{14}{463}$, $\frac{14}{464}$, and $\frac{14}{465}$). The relationship between these rocks and the commoner forms of the massif above described is very indefinite. Two of the occurrences appear to be close to the border of the great igneous mass,

one near Kudbi and the other a couple of miles east of Kolar bungalow. The third outcrop of diopside rocks is near Araku, where numerous small hills are capped with this rock, while the intervening ground is occupied by the commoner forms of the hypersthene rocks. In this last case I do not know the distance from Araku to the border of the massif, as I did not explore farther to the south-east.

Isolated outcrops of hypersthene rocks.

Numerous small hills of the same lithological character as the large massif, not indicated on the accompanying geologically coloured map, lie like islands in the schist complex, at distances up to three or four miles to the west of the western boundary of the main mass. The actual contact with the crystalline schists is nowhere exposed and the boundaries of the islands as well as of the main massif as marked on the geological map, are only approximate at best.

Igneous origin.

I am inclined to regard these hypersthene rocks as forming a great igneous *stock*, though it would be very difficult to prove conclusively that this is the case. My reference to this very interesting group of rocks is purposely brief, partly, because a detailed report can more properly be prepared after the completion of the survey of the great massif, and partly, because they have been so exhaustively studied from various parts of the Peninsula by Mr. T. H. Holland and described by him in a memoir now in the press.

IV.—CUDDAPAH SYSTEM.

The level plain extending from Kotpad to Nowrangapur, and south-east almost to Sashandi, offers very few points for geological observation, but wherever rocks are exposed, they are always found to be non-fossiliferous sediments. On this ground chiefly I have assigned them to the Cuddapah System.*

Secondary enlargement of quartz grains.

Near Kaliagura hæmatite quartzite, and ordinary quartzite are met with. The latter rocks in this section show in polarized light beautiful secondary growths of quartz on the old clastic grains. The interstices between the rounded grains of this former sandstone have been filled in by newly-deposited quartz substance, the crystallographic orientation of the new quartz always agreeing with that of the adjacent

clastic grains (specimen $\frac{14}{482}$). In several small ravines half a mile west of Sashandi outcrops of purple shales occur. Similar rocks were observed in the bed of the Indrabati river near Aoli. Three miles north of Kotpad, a few loose blocks of a calcareous hornstone were observed, though I was unable to find this rock *in situ*. These outcrops are only sufficient to lead one to suppose that the whole of the deeply alluvial-covered plain, of which Kotpad is the centre, is underlain by Cuddapah rocks. I have mapped it accordingly.

Other Cuddapahs.

Besides the Cuddapahs of the Kotpad plain, rocks of the same group occur along the Bastar-Jeypore boundary from Bansuli, near the confluence of the Jaura and Kolab rivers south-westward as far as the Lokli hills, where the Kolab finally leaves Jeypore territory. This strip of Cuddapah rocks is quite narrow, never more than four miles wide.

Jaura-Kondajori outcrops.

In the Jaura at Bunsuli purple siliceous dolomite is well exposed (specimen $\frac{14}{474}$). The general strike is north-easterly. Again some five or six miles south, near Kondajori small isolated hills of semi-metamorphosed red and white mottled dolomite occur. In some of these mottled dolomites peculiar coral-like structures abound. Though possibly of organic origin they are too badly preserved to enable one even to say definitely whether they are of organic origin or not (specimens $\frac{14}{457}$ and $\frac{14}{477}$). On the banks of the Kolab near Korokpur, and again at Talur purple slates and shales crop out.

Araguda limestone.

Farther south, at Araguda, due west of Ramagiri, the Kolab forms cascades as it cuts its gorge through nearly horizontal, grey, argillaceous limestone. In places the limestone has been dissolved away by the running water, giving rise to phantastic pillars, which are often capped by loose perched blocks, pierced by circular openings, or meeting to form arches. Caverns along the banks of the river are common. A mile or two north, probably in similar rocks (specimen $\frac{14}{478}$), occur the sacred caves of Gupteswar, where Hindu pilgrims assemble in large numbers for the annual feast which is held about the end of February.

Tetulguma conglomerates.

Near Tetulguma the Kolab traverses a highly metamorphosed conglomerate ;—the general mass of the rock is a very quartzose mica schist with pebbly bands an inch or two wide and from four to

eight inches apart. Within the pebbly bands the matrix of the pebbles is identical with the mica schist of the broad intervening bands, but the flattened pebbles appear to be uniformly of a somewhat more basic material. Were the pebbles and the matrix of the same chemical composition, one might be inclined to regard the conglomerate as of autoclastic origin, but this can hardly be accepted in view of the very different chemical composition of the pebbles and matrix (specimen $\frac{14}{486}$). At Tetulguma, as at Korokpur and Bansuli, the general strike is north-east to south-west.

Doubtful Cuddapahs.

The hills Lekki, Tulsi, and Lokli are not so definitely related to the Cuddapahs. They are, in general, composed of coarse, somewhat friable quartzite, not completely cemented by secondary quartz. On account of the friable nature of the quartzite, I have mapped them as Cuddapahs in preference to including them in the crystalline schists.

Dharwars (?).

Some of the quartzites along the boundary between the Cuddapahs and the schists bear a close resemblance to some of the Dharwar rocks. I thought them worth testing for gold, but on crushing and washing not even a colour of gold was obtained and unfortunately no fire assays were made.

V.—DIABASE.

Diabase.

Some of the small hills close to Jeypore are composed of a black compact rock resembling some of the intermediate forms of the hypersthene series. The microscope discloses it as a somewhat altered ophitic diabase. Some two miles west of Ramagiri similar rocks occur, but in them the augite and plagioclase have been altered, giving rise to an epidiabase. The outcrops are quite unsuited to determine the nature of the geological relationship, though on lithological grounds it is probable that these rocks occur as dykes (specimens $\frac{14}{466}$, $\frac{14}{467}$, and $\frac{14}{468}$).

VI.—DYNAMICS.

It has already been mentioned that the general strike of the oldest group of rocks, the crystalline schists, is north-west. This is the direction of the best foliation, though one often observes slickensides with a north-easterly direction. In the country surveyed the

hypersthene rocks without exception strike in a north-easterly direction. Thin sections of the gneissoid varieties of these latter rocks, when examined in polarized light, are usually seen to be so perfectly free from pressure and tension phenomena,—undulatory extinction and granulated borders of quartz grains for examples,—that one is compelled to conclude that the pressure acting at right angles to the foliation of the hypersthene rocks, which induced the foliation, must have acted at a time when the rock was in a distinctly plastic condition and very probably at a high temperature. The Cuddapah rocks when not horizontal, as in the case of the Araguda limestones, or quite massive as are some of the quartzites invariably, have an approximate north-eastern strike.

Two strike directions.

From these facts it may be deduced that the oldest rocks are the crystalline schists, which, before the intrusion of the great igneous massif, or the deposition of the Cuddapahs, were acted upon by an earth movement from the north-east or south-west, giving rise to the north-west foliation, which is quite wanting in the case of the younger groups of rocks. Later the hypersthene rocks were intruded and the Cuddapahs deposited, and a new force acted from north-west or south-east, giving rise to the foliation of these two rock groups and inducing the slickensiding of the crystalline schists. It must not be inferred from this, that when this second earth movement began, that the Cuddapahs were already deposited and that the hypersthene intrusion was taking place. This would mean that the hypersthene rocks are younger than the Cuddapahs, while the earth movement may have acted during a very long period, beginning with the intrusion of the igneous mass and giving rise to the uncrushed foliated rock from the plastic mass, while during the long period of its action the Cuddapahs were deposited, and the same strike imparted to them as had already been taken on by the hypersthene rocks.

Relative ages of the rocks.

It is remarkable that in this large area dykes are quite absent, unless we regard the few diabase outcrops as portions of dykes.

Absence of dyke rocks.

VII.—ECONOMIC GEOLOGY.

Nothing of special economic value has been discovered in the rocks of the area described in this report.

Iron.

Iron is manufactured locally in scores of villages scattered over the country occupied by the crystalline schists, though I have no knowledge of such occurrences outside that group of rocks. The ore varies from magnetite quartz-schist (specimen $\frac{14}{508}$) near Modpodor, concretionary limonite near Malsama, to compact limonite near Bagchua (specimens $\frac{14}{487}$ and $\frac{14}{516}$). There are no extensive workings, and I believe that the limonites are only superficial formations from which no great quantity could be obtained. Outcrops of quartz magnetite schist, however, belong to a different class, for in them the ore is a member of the crystalline schists, and in them larger quantities possibly, and of richer grade may be found by exploration. At present, however, in any case the great distance from any means of easy transport renders these ores comparatively valueless, and an industry of modern proportions is impossible. Under careful conservation the forests in the vicinity of Modpodor and Ramagiri are capable of furnishing an abundance of charcoal for iron working.

Iron smelting in Jeypore.

The method pursued by the villagers in manufacturing iron is very simple. Charcoal and iron ore, broken to about the size of walnuts, are mingled, and smelted in an upright cylindrical clay furnace about 8 inches in diameter and 30 inches in height. The furnaces are built into the wall of a pit, and supplied by means of the common bellows with blast from below. The iron produced appears to be of good quality, as it is used for making sickles, ploughshares, axes, and, in fact, almost all iron implements used by the villagers.

Potstone.

Potstone occurs to the south-west of Jeypore, towards Noaput and Outagaon, and is being used to a small extent for building purposes and for the manufacture of idols. It is much more abundant and of slightly better quality south of Kolar, though in none of the outcrops examined was the rock of a very high quality.

Limestone.

The limestone along the Kolab near Araguda, and possibly some of the limestone in the vicinity of Kondajori, could be used for the manufacture of lime, while some of the mottled dolomitic limestone from the latter locality are very pretty as ornamental stones when polished.

Reference has already been made to the quartzose rocks along the boundary between the Cuddapahs and the crystalline schists. Some of these rocks so closely resemble auriferous rocks of the Dharwar system, as to be worth prospecting. It is well known that in certain places along the Kolab the sands yield small quantities of gold on washing.

Gold (?)

Notes on the Relationship between *the* Productus limestone *and the* Ceratite formation *of the* Salt Range, *by* FRITZ NOETLING, Ph. D. (Berlin), F. G. S., *Palæontologist, Geological Survey of India.*

1.—INTRODUCTION.

Ever since Dr. Fleming's discovery of a rich fauna in beds which he called "Productus limestone" the latter have excited the greatest interest amongst geologists. Dr. Fleming's collection was sent to Europe, and owing to the frequency of *Producti* the strata containing this fauna were pronounced to belong to the carboniferous system, and were correlated with the mountain limestone series. But not only did Dr. Fleming collect palæozoic brachiopods, but also a considerable number of ammonites, which belonged exclusively to the group of *Ceratitidæ*; his statement that they occurred together with the *Producti* was discredited and considered to be based on wrong observations. Yet Dr. Fleming's statement was by no means such an erroneous one, as it was generally believed to be, and if the evidence had been considered not so much from the standpoint of the geological dogma, our views regarding the age of the productus limestone and the ceratite formation would have been altered long ago.

On the authority of Dr. Verneuil, Davidson, Dr. Koninck, and Murchison, the productus limestone was pronounced to be of carboniferous age, and this view Mr. Wynne adopted in his excellent memoir on the Salt Range; he considered the productus limestone to be carboniferous and the "ceratite formation" as triassic. This is to be regretted, as Mr. Wynne himself noticed the very gradual passage from the productus beds into the ceratite formation, and it will be admitted that if we assume the productus limestone to be carboniferous, it is *primâ facie* impossible that the ceratite formation can represent the triassic system, and if we consider the ceratite formation to be triassic, the beds underlying the same cannot possibly represent the mountain limestone, considering the gradual passage which exists between the two series of beds.

The late Professor Waagen was originally inclined to believe in the carboniferous age of the productus limestone,[1] but as the determination of the fossils progressed, he felt himself obliged to change his views considerably, and after various alterations he finally decided that the productus limestone plus the lavender clay and speckled sandstone represented the permo-carboniferous and the whole of the permian system.[2]

In his subsequent publications dealing with the ceratite formation, Professor Waagen stated positively that there existed a breah between the ceratite formation and the productus limestone and that the equivalents of the *Otoceras beds* of the Himalayas were absent in the Salt Range.

When I visited the Salt Range for the first time in January 1894, I had an opportunity of observing the fine section in the Chideru ravine. The strata exposed range from the lavender clay up to the upper ceratite limestone, though owing to a local fault, the lower productus limestone could not be observed. It is sufficient for our purposes to say, that an uninterrupted sequence of beds from the middle productus limestone (Kalabagh beds, Waagen), up to the upper ceratite limestone (zone of *Stephanites superbus*, Waagen), could be observed I noticed at once that there existed a gradual passage between beds which owing to the occurrence of *Productus indicus* unquestionably belonged to the permian, overlaid by beds which contained numerous though ill-preserved specimens of *ceratites*.

1 Mem. Geolog. Survey of India, Vol. IX., p. 353.
2 Salt Range Fossils. Geological Results, p. 241.

species. Unfortunately I had not sufficient time to study this section in detail and my notes were put aside until a more favourable opportunity should arrive.

When returning from Baluchistan in November 1898, I paid another hurried visit to Chideru in order to verify my previous observations; but before publishing the results, it was deemed necessary that I should devote more time to the study of the productus limestone and the triassic beds at other localities in the Salt Range. I was consequently deputed during the field season 1899-1900, to the Salt Range, where I visited and carefully examined the sections near Virgal, Warcha and Chideru. Although there are still many other localities which could not be visited, the study of the above sections has proved with absolute certainty the existence of a gradual passage between productus limestone and ceratite formation. This is no new discovery so to speak, because Mr. Wynne had already noticed the same, but my observations proved enough to show that Waagen's belief in an unconformity between the productus limestone and the ceratite formation, which he has distinctly set forth[1] in the now famous paper on the sub-division of the triassic system is absolutely erroneous. But more than that, I succeeded in discovering a species closely related to *Otoceras*, not as I expected, below the lower ceratite limestone, but actually right in the middle of the ceratite marl, thus not only proving that *Otoceras beds* exist in the Salt Range, as I have always maintained on stratigraphical grounds, but that the ceratite marls have to be considered to be the equivalent of the *Otoceras* beds.

In addition to the above I discovered that the main layer of *Xenodiscus carbonarius*, Waagen,[2] is considerably lower down in the sequence than believed to be by Waagen. A few more observations regarding the boulder bed, speckled sandstone and the lower productus limestone enabled me to trace satisfactorily the relations between the glacial palæo-dyas and the marine neo-dyas.

It would be out of place to go into details in a preliminary note, and I reserve to myself the right of being more explicit in a subsequent paper. It will be perfectly sufficient if I give here the section near Chideru, and also set forth the sub-division of the productus lime-

[1] Entwurf einer Gliederung d. pelag. Sedimente d. Trias Systems. Sitzungsber d. K. K Akademie d. Wissensch, 1895, Vol. CIV, Pt. 1, p. 1271 ff.

[2] In order not to cause mistakes I retain Waagen's name, though in many cases I do not agree with him as to the correctness of the determinations.

stone and ceratite formation as adopted by me on the strength of my recent observations.

2.—SECTION IN THE CHIDERU RAVINE.

The small village of Chideru is situated in the western part of the Salt Range, about 12 miles north of Wanbachran railway station, and therefore easily accessible during all times of the year. To north-east of the village, which is right at the foot of the hills, a tortuous and wild glen cuts through a low range, which is succeeded by a fairly broad valley; it is here where the passage between productus limestone and ceratite formation can best be seen.

At the foot of the hills a detached mass of middle productus limestone, dipping at a high angle towards west, and disappearing under the alluvial deposits will be met with. It is much shattered and separated by a small fault from a purple coloured sandstone. The latter is followed by the lavender clay the beds of which form a distinct flexure. Above the lavender clay follows a series of beds, the exact nature of which could not be ascertained as they are covered with debris from the middle productus limestone. Then follows the middle productus limestone, obviously a slipped mass, which is separated from the main range by a fault. In the main range we first have a slope, covered with talus, probably hiding the lower part of the middle productus limestone, then the middle productus limestone forming a precipice facing west, and dipping about 50°-60° north-east. Then follows in an uninterrupted series, the upper productus limestone, and the ceratite formation, which dips towards the productus limestone on the northern side of the valley, thus proving the existence of another fault. In descending order the section is as follows:—

	Ft.	in.
26. Whitish calcareous sandstone	12	0
25. Stachella sandstone	5	0
24. Olive coloured, thin bedded limestone, alternating with marls of the same colour (Zone of *Stephanites superbus*).	50	0
23. Olive coloured, somewhat brownish, rather hard calcareous sandstone, with numerous specimens of *Flemingites flemingianus*, Waagen, and *Aspidites superbus*, Waagen (Zone of *Flemingites flemingianus*).	10	0

		Ft.	in.
22.	Dark bluish green marls having a few thin layers of limestone imbedded. Fossil very common, the following Zones could be distinguished— Zone of *Koninckites volutus*, Waagen. Zone of *Prionolobus rotuntatus*, Waagen. Zone of *Celtites* spec.	100	0
21.	Dark brown, hard and flaggy limestone with numerous ill-preserved fragments of *Ceratites*	3	0
20	Green marl	2	0
19.	Dark brown, hard and flaggy limestone with numerous ill-preserved fragments of *Ceratites*	5	0
18.	Light brown, thinly-bedded sandstone separated by argillaceous layers	2	6
17.	Limestone of rusty brown colour, hard and ringing under the hammer; indistinct traces of *ammonoidea* . .	0	4
16.	Light brown, thinly-bedded sandstone separated by argillaceous layers	3	0
15.	Hard, dark, calcareous sandstone, full of small fragments of shells, apparently *Bellerophon* (?) or *Stachella.*	0	6
14.	Shaly calcareous sandstone of brown colour, apparently unfossiliferous	3	6
13.	Hard, dark brown, calcareous sandstone separated by argillaceous layers, full of fragments of shells (*Bellerophon* (?) or *Stachella*).	4	3
12.	Brown clay	0	4
11.	Thickly-bedded rather soft sandstone of pale yellow colour forming a very continuous bed, subdivided by a few argillaceous layers only. Unfossiliferous.	5	6
10	Light brown clay, with strings of calcareous sandstone and gypsum, unfossiliferous	12	0
9.	Hard limestone of light brown colour, full of— *Bellerophon impressus*, Waagen . . . *Schizodus pinguis*, Waagen.	1	6
8	Soft yellowish sandstone, unfossiliferous . . .	4	0
7.	Soft sandstone of light yellow colour, full of large specimens of *Productus indicus*, Waagen	9	0
6.	Soft sandstone of dark brown colour containing numerous specimens of— *Productus indicus*, Waagen, *Oldhamina decipiens*, Koninck, *Dentalium herculaneum*, Waagen .	25	0
5.	Soft rusty brown sandstone, with hard calcareous layers, full of— *Derbyia hemispherica*, Waagen . .	120	0

	Ft.	in.
4. Hard, brown sandstone in thick layers apparently unfossiliferous	65	0
3. Yellow sandstone with hard streaks, full of— *Productus indicus*, Waagen, *Productus cora*, d'Orbigny . . .	50	0
2. Greenish clay apparently unfossiliferous . . .	25	0
1. Hard nodular limestone of grey colour, full of fossils, thickness not measured, but representing the typical middle productus limestone.		

If we go through the above section, the single beds of which, as cannot sufficiently be emphasised, pass so gradually into each other, that it is frequently difficult to draw the boundary between the same, we may observe that there cannot be the slightest doubt as to the age of the beds 1, 2 to 9, and 17 to 26.

The beds 17 to 26 represent the ceratite formation in its horizons as distinguished by Wynne, *viz.*:—

		Ft.	in.
25, 24, 23	Upper ceratite limestone and ceratite sandstone .	77	0
22	Ceratite marls	120	0
21 – 17	Lower ceratite limestone	12	10

The beds 2 to 9 unquestionably represent the upper productus limestone. Bed 1 represents the middle productus limestone.

There remain therefore only beds 16 to 10 having an aggregate thickness of 29′ 1″, the stratigraphical position of which remains somewhat uncertain for the present, owing to the absence of distinct fossils. The lithological character of the beds from Nos. 15 to 10 is however such that I would unquestionably include them in the upper productus limestone as it is more in accordance with the lower than with the upper beds. It is extremely unfortunate that the fragments of the shells are so minute, that it is impossible to say whether they belonged to the genus *Bellerophon* or *Stachella.*

The above section proves unquestionably the gradual passage between the productus limestone and the ceratite formation; but in order to understand the conditions more clearly we may summarise the lithological facts in the following way:

In the middle productus limestone hard, white limestone in thick beds prevails. This is gradually replaced by soft limestone of brownish colour separated by argillaceous beds of considerable thickness, in various tinges of yellow or brown. The colour of the

shales gradually darkens to bluish green, as can be particularly well seen near Vergal; and the limestone bands become more subordinate. The lower part of the ceratite marl is dark blue, but the colour gradually gets lighter, at the same time thin beds of limestone, argillaceous limestone, even sandstone, make their appearance, and towards the close of the series whitish beds appear.

Whatever view may eventually be held with regard to the ceratite formation I cannot sufficiently emphasise the fact that stratigraphically it belongs to the productus limestone series, from which it cannot possibly be separated, and any attempt at a sub-division must absolutely and solely be based on palæontological grounds.

3.—NOTES ON THE PRODUCTUS LIMESTONE.

Further east of Chideru a very fine section from the middle productus limestone up to the base of the ceratite formation can be seen. The beds are here particularly rich in fossils. It was at this place that I discovered the main layer of *Xenodiscus carbonarius* which occurs in about the topmost 20 feet of the middle productus limestone together with *Productus indicus.*

Under these circumstances it is no longer admissible to distinguish a separate cephalopod bed within Waagen's meaning, in the upper productus limestone, particularly if we keep in mind that the cephalopods in this group are extremely rare.

Unfortunately I had no opportunities of studying the lower productus limestone in greater detail, because it is nowhere well developed in the localities which I have visited. I have, however, been able to ascertain, that if developed together at the same place, the glacial boulder bed is always the oldest in the series; this is overlaid by the speckled sandstone beds, which in their turn are followed by the lavender clay; the lavender clay passes gradually into the lower productus limestone.

So far only very few fossils have been found in the lower part of the series, namely, bivalve casts and *Conularia* nodules.

The productus limestone fauna makes its appearance very suddenly, and in the lowest fossiliferous bed which I could discover the same fauna prevails as in higher beds.

The following is the sub-division of the permian in the Salt Range according to my interpretation :—

<table>
<tr><td rowspan="5">Trias.</td><td rowspan="5"></td><td rowspan="5">Baktrian.</td><td>Upper ceratite limestone.</td><td colspan="2">Zone of *Stephanites superbus*, Waagen.</td></tr>
<tr><td>Ceratite sandstone.</td><td colspan="2">Zone of *Flemingites flemingianus*, Waagen.</td></tr>
<tr><td rowspan="2">Ceratite marls.</td><td rowspan="3">Otoceras beds.</td><td>Zone of *Koninokites volutus*, Waagen.</td></tr>
<tr><td>Zone of *Prionolobus rotuntatus*.</td></tr>
<tr><td>Lower ceratite limestone.</td><td>Zone of *Celtites spec.*</td></tr>
<tr><td rowspan="5">Marine Neo-Dyas.</td><td rowspan="7">Zechstein.</td><td rowspan="7">Sindian.</td><td rowspan="3">Upper productus limestone.</td><td colspan="2">Zone of *Euphemus indicus*, Waagen.</td></tr>
<tr><td colspan="2">Zone of *Derbyia hemisphærica*, Waagen.</td></tr>
<tr><td colspan="2">Zone of *Productus lineatus*, Waagen.</td></tr>
<tr><td rowspan="3">Middle productus limestone.</td><td colspan="2">Zone of *Xenodiscus carbonarius*, Waagen.</td></tr>
<tr><td colspan="2">Zone of *Lyttonia nobilis*, Waagen.</td></tr>
<tr><td rowspan="2">Marine Palæo-Dyas.</td><td colspan="2">Zone of *Fusulina cattaensis*, Waagen.</td></tr>
<tr><td>Lower productus limestone.</td><td colspan="2">Zone of *Spirifer marcoui*, Waagen.</td></tr>
<tr><td rowspan="4">Glacial Palæo-Dyas.</td><td rowspan="4">Roth-liegendes.</td><td rowspan="4">Dravidian.</td><td rowspan="4">Speckled sandstone.</td><td colspan="2">Lavender clay, unfossiliferous.</td></tr>
<tr><td rowspan="2">Specked. sandstone.</td><td>Zone of *Conularia lævigata*, Waagen.</td></tr>
<tr><td>Zone of *Eurydisma globosum*, Waagen.</td></tr>
<tr><td colspan="2">Boulder-bed.</td></tr>
</table>

Progress report on the Survey of Spiti and adjoining areas, *by* H. H. Hayden, B.A., B.E., *Officiating Deputy Superintendent, Geological Survey of India.*

In order to resume the work begun in the summer of 1898, I returned to Spiti in May of last year. I was accompanied on this occasion by my colleague, Dr. A. von Krafft, to whose valuable assistance must be attributed much of the progress made during the past season.

A short summary of the results obtained in 1898 has already been published in the last "General Report," 1898-99,[1] from which it will be seen that special attention was paid to the older beds of Spiti, including the palæozoic group and the lower trias. The chief object in view, therefore, during the past season was to examine, in as great detail as was possible in the time at our disposal, the remainder of the mesozoic group, and also to complete the geological map of Spiti and carry the survey, as far as possible, into the adjoining areas. Although much of this has been accomplished, and the results obtained have proved to be more comprehensive and more important than we had expected, yet a few points still remain doubtful and it is desirable, before publishing an account having any pretensions to completeness, that these should be cleared up by a short visit to certain localities, which owing to want of time have hitherto received less attention than they deserve.

The earlier part of the past season was devoted to an examination of the whole sequence of rocks found in the valleys of the Pin and Parahio rivers. I then left Spiti and crossed the Mánirang pass into Bashahr, where I completed the map of the north-western portion of that state, working round eventually to the junction of the Spiti and Pára rivers, whence I crossed a portion of Hundes, striking British territory again at Chágya Sumdo in Rupshu. I thence worked up to Tso[2] Moriri and mapped as much as was possible of the portions of Rupshu adjoining Spiti, returning to Kibber *via* the Párang La.[3] In the meantime Dr. Krafft, who had remained in Spiti, had been engaged in mapping some of the north-eastern parts of that area,

[1] See pages 11 to 22 and 46 to 50.
[2] Tso=lake.
[3] ;

and in working out in detail the whole of the mesozoic group from lower trias to cretaceous : he then joined me at Kibber and we worked out *via* Losar and the Hamta pass to Kulu.

SPITI AND BASHAHR.

Palæozoic Group.

Haimanta system.—There is little to add to the notes made in 1898 with reference to this system : we have still failed to find in Spiti any trace of the lowest sub-division, as seen in the eastern Himalayas, *viz.*, that characterised by the prevalence of conglomerates.[1]

Middle haimantas.

The middle division, as seen in Spiti, was described in the previous summary. In Bashahr it is exposed in the Thanam and Sutlej valleys and consists in the former locality of quartzites and slates with beds of grit towards the top.

In the Sutlej valley below Hango the rocks of this division have been much altered by intrusive granite and are represented chiefly by quartz schists and garnetiferous mica schists with Kyanite.

Upper haimantas.

The upper haimantas (" red quartz shales " of Mr. Griesbach[1]) are well developed in Bashahr, and are more characteristic than in Spiti. They consist of dark blue, black and green magnesium slates, weathering bright red and yellow, with subordinate bands of quartz schist and black carbonaceous shale,—the whole having a thickness of not less than 1,000 feet.

Upper cambrian " trilobite beds."

It has already been recorded (see previous report) that in the valley of the Parahio river in Spiti, these " red quartz shales " are overlain by a series of quartzites and slates, with thin bands of reddish brown dolomite, and in these beds upper cambrian *trilobites* were found in 1898. Wherever the upper haimantas have been found, careful search has been made for these "trilobite beds," but except in the Pin valley near Muth, fossils have not been discovered in any new locality.

[1] Mem., G. S. I., vol. XXIII, p. 51.

A detailed examination of the original section in the Parahio valley proves that an important unconformity exists between this series and the overlying silurian grits and quartzites. The highest member of the upper cambrian is a thick bed of reddish-brown dolomite, which is apparently always overlain by one or more bands of conglomerate. The lowest of these bands is made up of fragments of the dolomite, and varies in thickness from about five feet to nearly two hundred; in the former case it lies on an eroded surface of the dolomite, but in the latter, it completely replaces the dolomite, and rests unconformably on the shales and quartzites of the "trilobite beds."

Cambro-silurian unconformity.

The upper conglomerate is composed of fragments of quartzite probably derived from the upper and middle haimantas, and has been found in every section examined, whereas the lower or dolomite conglomerate is occasionally absent, as is the case in the Thanam valley. The boundary between the upper cambrian and silurian systems should probably be taken at the base of these conglomerates, and not, as was originally suggested, at the base of the reddish-brown dolomite: this assumption, however, is based merely on the intimate lithological connection between the dolomite and the underlying beds, for no fossils of lower silurian age have yet been found in Spiti.

Silurian.—It is possible that no lower silurian rocks occur in this area, for there is no trace of the "lower silurian *coral* limestone" found by Mr. Griesbach in the Niti sections, its place being apparently taken in Spiti by the upper cambrian trilobite beds and conglomerates (in the Parahio valley), and by the conglomerates, with portions of the trilobite beds, in the Pin valley and other localities.

Lower silurian?

Throughout Spiti the higher conglomerate passes up gradually into the great system of red grits and quartzites referred by Mr. Griesbach to the upper silurian. In Spiti no trace of fossils has been found in this series, but it is overlain by some 650 feet of shales, and limestones containing an undoubted upper silurian fauna, and its age is therefore probably either middle or lower silurian.

The upper silurian rocks were briefly described in my previous report. Further collections made, during the past season, include several specimens of *Calymene* sp., numerous *brachiopods* and very fine specimens of

Upper silurian.

Halysites catenularia, Lmck., and the assumption of an upper silurian age for these beds has now been confirmed.

Devonian ?

The grey coral limestone containing *Halysites catenularia* is overlain by about 100 ft. of hard, grey, siliceous limestone, weathering brownish-red (—"red crinoid limestone," Griesbach). A few fossils have been obtained from this limestone, but they are not sufficiently well-preserved to throw much light on the question of the age of the rock: its position, however, —immediately overlying upper silurian beds—would indicate a devonian age. But further search in the sections near Lio in Bashahr would probably result in the discovery of better fossils.

The red crinoid limestone passes up gradually into a reddish quartzite, which in turn shades off into the white (Muth) quartzite.

Carboniferous and permian.—In the section near Muth—"southern facies" (Stoliczka)—this quartzite is overlain by a few hundred feet of limestone which is separated from the overlying permian sandstone and productus shales by a thin bed of conglomerate, while in the sections in lower Spiti (the "eastern facies"), the productus shales and their associated sandstone (or sandy limestone) are underlain by conglomerates which pass down into several thousand feet of alternating shales and quartzites, and neither the white (Muth) quartzite, nor the overlying limestone, are seen: it was, therefore, supposed by previous observers (Stoliczka and Griesbach) that an unconformity existed between the carboniferous limestones and the productus shales. This unconformity—which occurs at the base, not of the productus shales but of the permian calcareous sandstone, which everywhere immediately underlies the productus shales—has now been traced throughout the whole length of Spiti and northern Bashahr. In Spiti the characteristic facies of the upper palæozoic is the southern of Stoliczka, *viz.*, the white (Muth) quartzite overlain by a relatively small thickness of grey limestone, upon which the permian sandstone rests unconformably. At the head of the Thanam valley, the limestone gradually disappears and the sandstone lies on the white quartzite, which, however, as the outcrop is followed from west to east, also dies out, and so on with the underlying beds until the permian sandstone is found resting with apparent conformity on the red silurian quartzite. Higher beds then gradually re-appear, and at the Hangrang pass, between Sungnam and Hango, the sandstone rests on the lower beds of the upper silurian limestones. North of Hango the white (Muth) quartzite

is again seen in small patches, gradually increasing in thickness, till above Lio in the valley of the Lipak river, what appears to be a complete section of the carboniferous and permian beds is found. The section up to the top of the Muth quartzite is perfectly normal; these follow in *ascending* order :—

(*a*) grey limestone,
(*b*) alternating beds of limestone, shale and quartzite, with a thin band of conglomerate,
(*c*) thick mass of hard, dark limestone, with some flaggy sandstones and slates,
(*d*) shales and quartzites (the "eastern facies"),
(*e*) conglomerates and grits passing up into calcareous sandstone (permian),
(*f*) productus shales.

This is probably the most complete section of carboniferous and permian beds yet known in the Himalayas, and the total thickness from the base of the Muth quartzite to the base of the productus shales is certainly not less than 5,000 feet.

Grey limestone: ? upper carboniferous.

Fossils have been found in *a*, *c*, *d*, and *e*. In the lowest bed (*a*),—"upper carboniferous limestone (8*a*)" of Griesbach[1]—*brachiopods* are common, but as a rule badly preserved: they include the genera *Productus*, *Athyris*, *Dielasma Derbyia* and *Syringothyris*, the last-named being the commonest, and being represented by at least two species, which, however, owing to the bad state of preservation of the specimens cannot be identified with certainty. One species, however, is indistinguishable from a form described by Dr. Diener[2] as *S. cuspidata*, Mart. Diener's specimen was collected by Stoliczka near Kuling in Spiti, where this limestone is exposed; the specimen, however, would seem too fragmentary to warrant specific identification.

? Permian.

Fossils occur at several horizons in the sub-division (*c*) These include species of *Syringothyris*, *Spiriferina*, *Rhynchonella* (cf. *pleurodon*, Phill.), *Discina*,

[1] Mem., G. S. I., Vol. XXIII, p. 216.

[2] Pal. Indica, ser. XV, Vol. I, pt. 2, p. 76. Dr. Diener infers that the specimen was collected from a lower carboniferous limestone which, in Niti, occur below the white (Muth) quartzite; this bed, however, is not exposed at Kuling, the lowest member of the section being the white quartzite. The matrix, too, is indistinguishable from that of specimens collected by us in Spiti in the *upper* limestone (8*a*). His inference of a lower carboniferous age is therefore hardly justified.

Athyris, *Productus*, *Chonetes*, *Derbyia*. As a rule the specimens are too poor to be identified specifically, but they strongly resemble forms from the productus limestone of the Salt Range and are probably of permian age. A pygidium of *Phillipsia*, closely resembling *P. cliffordi*, Woodw., was also found in these beds.

Probable representatives of the "Productus Limestone."

In the time at my disposal it was possible to make only a superficial examination of this section, but the resemblance between the series of quartzites and limestones and the productus limestone series as seen on the North-West Frontier is very striking, and it is probable that a detailed investigation would throw considerable light on the true relation and extent of the carboniferous and permian systems of the Himalayas.

"Fenestella shales."

The overlying shales and quartzites attain a thickness of about 4,000 feet, but are rarely fossiliferous. Near Po, however, some of the higher shale bands contain large numbers of *Bryozoa* chiefly *Fenestella*, and these beds probably represent the Barus or Zewán beds of Kashmir. *Brachiopods* also occur, but they are very badly preserved.

Conglomerates.

These shales and quartzites are overlain by grits and conglomerates of varying thickness, passing up into a coarse calcareous sandstone or sandy limestone. Fossils, chiefly *Producti*, occur in the grits, but they are badly preserved as a rule. The calcareous sandstone, however, contains numerous *brachiopods*, among which the following forms have been recognised:

Permian sandstone.

Spirifer musakheylensis, Dav.
„ cf. *nitiensis*, Diener.
Athyris gerardi, Diener.
„ *subtilita*. „
Productus purdoni, Dav.
Martinia glabra, Mart.
Dielasma sp.

In Spiti and Bashahr this bed invariably accompanies the productus shales, with which it seems always to be intimately connected. Below it occurs the great unconformity which is so strongly marked in the southern parts of Spiti and in the Thanam valley.

Correlation of conglomerate of Po with Blaini beds probably incorrect.

The underlying conglomerates, which are well seen near Po and Dankhar, were supposed by Mr. Oldham, who visited these localities, to be of glacial origin, and it was suggested that they might be homotaxial with the boulder slates of the Blaini series.[1] These again have been correlated with the Talchir and Salt Range boulder-beds.[2] My doubts as to the correctness of the former correlation on lithological grounds, have already been stated.[3] These doubts have been considerably strengthened by the discovery of the limestones and quartzites of the Lipak river; for if, as seems probable, they are the equivalents of the productus limestone of the Salt Range, then the *overlying* conglomerates must be considerably younger than the Salt Range boulder bed. This emphasises the necessity for a more detailed investigation of the Lipak limestones.

At the north-west end of Spiti also, at Losar, the carboniferous-permian beds are almost, if not quite, as thick as at Lio; but at the time of our visit the country was almost completely covered with snow and it was impossible to examine the beds in any detail. It is evident, however, that throughout the greater part of Spiti these systems are comparatively thin, but, towards both the north-western and south-eastern boundaries, they suddenly increase in thickness.

Productus shales.

Further collections of ammonites have been made from the upper part of the productus shales, but they have not yet been worked out.

Classification of the palæozoic systems.

The following table contains a rough classification of the palæozoic systems of Spiti and Bashahr, referred as nearly as is at present possible, to their probable European equivalents.

Black shales=" Productus shales."	With *Xenodiscus carbonarius*, Waag., *Cyclolobus* cf. *oldhami*, Waag., and other cephalopoda in the upper part, and the usual *brachiopoda* of the "productus shales" in the lower.	Carboniferous and permian.

[1] Records, G. S. I., Vol. XXI, p. 151.
[2] Manual of the Geology of India, 2nd Ed., pp. 135, 206.
[3] General Report, G. S. I., 1898-99, p. 48.

Calcareous sandstone or sandy limestone, underlain by grits and conglomerates.	With *Spirifer musakheylensis*, Dav., *Athyris gerardi*, Diener, *Athyris subtilita*, Diener, *Productus purdoni*, Dav., *Martinia glabra*, Mart., *Dielasma* sp.	Carboniferous and permian.
Alternating beds of shale and quartzite. Limestones, slates and quartzites.	With numerous *bryozoa* and *brachiopoda*. With *Phillipsia* cf. *cliffordi*, Woodw., *Syringothyris* sp., *Spiriferina* sp., *Rhynchonella* cf. *pleurodon*, Phill., *Discina* sp., *Athyris* sp., *Productus* sp., *Chonetes* sp. and *Derbyia* sp.	
Grey limestone, often oolitic and crinoidal.	With *Productus*, *Athyris*, *Dielasma*, *Syringothyris* (the last named genus very common).	
White quartzite = "Muth quartzite" (Stoliczka).	Apparently unfossiliferous . .	? Carboniferous.
Grey siliceous limestone, weathering brownish red = "Red crinoid limestone" (Griesbach).	With fragments of *crinoids* and *brachiopods*.	? Devonian.
Limestones, marls and slates.	With *Halysites catenularia*, Lmck., and other corals in the upper beds and *Calymene* sp., *Strophomena* sp., in the lower.	Upper silurian.
Red gritty quartzite, underlain by conglomerate.	Apparently unfossiliferous . .	? Lower silurian.
Slates and quartzites, with a few bands of dolomite.	With upper cambrian *trilobites* .	Upper cambrian.
Red quartz-schists, slates and carbonaceous shales.	......	Upper haimanta.
Quartzites and slates .	......	Middle haimanta.

MESOZOIC GROUP.

Trias.—During the season of 1898 work was confined chiefly to the lower trias including the "Otoceras beds," "Subrobustus beds" and Muschelkalk, from all of which collections were made. These collections were examined by Dr. A. von Krafft (see "General Report," 1898-99, p. 11) and were found to include some new and interesting material. During the past season considerable additions—chiefly of new or rare forms—have been made to those collections, but attention was chiefly directed to the upper trias, from which collections were made while the whole sequence of beds was examined, so far as was possible in the time at our disposal. During the past few months these collections have been examined by Dr. Krafft, and the following notes are based chiefly on the results of his investigations, of which a fuller account will be found in Dr. von Krafft's paper in this year's "General Report." Most of the upper triassic horizons known in the eastern sections of the Himalayas have been recognised in Spiti, where, however, the fossils contained in them are often small in number and badly preserved: but some compensation for this is found in the existence in Spiti of other horizons rich in fossils, hitherto unrecorded from the Himalayas.

Lower trias. "Otoceras beds."

The productus shales are overlain by about six feet of black limestone and shale—the "Otoceras beds" of Niti. *Otoceras* is rare, the most characteristic genera being *Ophiceras* in the lower layers and *Meekoceras* in the upper.

This bed is overlain by grey, thin-bedded earthy limestones, alternating with narrow bands of shale. These represent the "subrobustus beds" (Diener) of the eastern sections. This term, however, is not applicable to the Spiti area.

These are overlain by a thick bed (60 ft.—90 ft.) of grey nodular limestone, in which fossils are very rare and, with the exception of one form (*Nautilus* ex. aff. *N. palladii*, Mojs.), too badly preserved to be identified.

Muschelkalk.

The next series—muschelkalk—consists of grey concretionary limestone in beds about one foot thick, separated by thin bands of shale. The lowest

bed contains lower muschelkalk forms together with *Ceratites subrobustus*, E. von Mojs.

Separated from this by a thin parting of shale is another band of limestone containing numerous brachiopods, the commonest being *Spiriferina stracheyi*, Salt. This is overlain by the remainder of the muschelkalk with the usual fossils, *viz.*, *Ptychites gerardi*, Blanf., *Ptychites rugifer*, Oppel, etc.

Ladinic Stage well represented.

The muschelkalk is overlain by a series of calcareous shales with thin bands of limestone, containing several species of ammonites as well as large numbers of *Daonella indica*, Bitt. and *D. lommeli*, Wiss. The prevalence of this characteristic ladinic species is very interesting, and it would seem that that stage is amply represented in Spiti and includes a considerable thickness of beds hitherto supposed to be of carnic age. The hiatus said to exist in the eastern sections between the muschelkalk and the upper carnic is therefore probably only local.

These "daonella shales" pass up gradually into a series of dark splintery and flaggy limestones with thin bands of shale. *Daonella lommeli*, Wiss., has been found in the lower beds, but in the upper is apparently replaced by species of *Halobia*.

This limestone is overlain by a thick series of light grey calcareous shales with dark limestone bands, containing, as a rule, few fossils. The lowest bed of this series is a dark grey shale full of black cherty concretions containing fossils, chiefly *Trachyceras* (cf. *aonoides*) and *Joannites cymbiformis*, Waag. The overlying shales and limestones contain also species of *Halobia* and *Megalodon*, and a band rich in brachiopods including *Spirifer shalshalensis*, Bitt., and *Rhynchonella lankana*, Bitt. Towards the top, limestones are more numerous, the series gradually becoming one of limestone with subordinate bands of shale. These beds, which contain *Tropites* cf. *Sub-bullato*, v. Hau., and *Clydonautilus griesbachi*, E. v. Mojs., presumably represent the "Tropites limestone" of Kalapani, but the fossils are few and badly preserved.

Above this series is a great mass of hard dolomitic limestone, which has yielded only *Megalodon* and a few *brachiopods* and *lamellibranchs*. It is overlain by sandy limestones, flaggy sandstones and dark micaceous shales. The limestones contain bivalves and ammonites, the latter including *Paratibetites* aff. *tornquisti*, E. v. Mojs.,

and ? *Hauerites* sp. The sandstones are full of badly-preserved plant remains, and the shales contain numerous concretions containing chiefly *Juvavites* sp., and *Paratibetites tornquisti*, E. v. Mojs., a fauna resembling that of the "Halorites beds" of the eastern sections.

The next bed, which forms a very characteristic horizon in Spiti and Rupshu, consists of a hard grey or white dolomitic limestone full of corals, amongst which a very common form is one resembling *Lithodendron*. Other fossils are rare, but *gastropods* occur in Rupshu and *brachiopods* — including *Spiriferina griesbachi*, Bitt., were found by Dr. Krafft near Lilang. This limestone may be equivalent to the "*Spiriferina griesbachi* beds" of Niti.

Above the main mass of the limestone are thin-bedded earthy limestones containing badly preserved fragments of ammonites.

These beds are overlain by flaggy sandstones and shales, strongly resembling the series immediately underlying the coral limestone. Fossils occur near the top of this series, chiefly in two horizons, the lower of which consists of a band composed entirely of remains of *Monotis salinaria*. The higher horizon lies at the top of the shales, and is very rich in fossils, chiefly *Spiriferina griesbachi*, Bitt., which occurs in enormous numbers. Immediately above this horizon are some bands of limestone containing a large bivalve fauna.

The overlying beds form one of the most constant and characteristic horizons of the upper trias of Spiti, and consist of a series of white and brown quartzites, with subordinate limestone bands. The white quartzite bed can be seen at a distance of several miles running as a thin white band among the darker beds in the high cliffs of the upper trias. With the quartzites are intercalated limestones, amongst which is a characteristic bed containing numerous very large specimens of *Megalodon* sp. This bed is found everywhere, but is specially well marked in the Para valley, north of the Parang La, where a very fine *Megalodon* was obtained. Numerous sections of a bivalve nearly two feet in diameter occur in this bed, and probably represent *Dicerocardium*, but no specimens could be obtained. This is the characteristic horizon in Stoliczka's "Para limestone."

Dachsteinkalk.

Above this quartzite series is a great mass of limestone over 2,000 feet thick, probably representing the uppermost trias, the rhætic, and much of the

jurassic (lias to probably middle jurassic). Fossils are rare in the lower part of this limestone.

Jurassic.—About the middle of the series fossils become more numerous and resemble liassic types, among these being a *Spiriferina* cf. *obtusæ*, Opp., which occurs about 900 feet above the base of the series; about 1,000 feet higher up an ammonite almost identical with *Stephanoceras coronatum* of the Kelloway was found by Dr. von Krafft, and above this, *brachiopods* occur in very large number.

Much of this limestone was included by Dr. Stoliczka in his "lower Tagling limestone," which he believed to be of liassic age; it is probable, however, that the uppermost beds are younger, probably middle jurassic. The *upper Tagling limestone* which was said to occur only on the Baralatse range, where he found it on the Tagling and Parang passes, proves to be in reality a lower portion of his lower Tagling limestone, which has been brought by an inversion above the higher beds of the same series, its age being probably liassic. These beds are well seen on the saddle of the Parang La.

Spiti shales.

A few fossils were collected from the Spiti shales, but they are not likely to add to our knowledge of the series, previous collections having been very large.

Gieumal sandstone.

Cretaceous.—The Gieumal sandstone was examined in some detail by Dr. Krafft and many fossils, chiefly bivalves, collected.

Chikkim limestone.

The overlying Chikkim limestone, which, in the neighbourhood of Chikkim, has yielded only *Foraminiferæ* similar to those previously collected by Stoliczka, in the Lingti valley, contains also *Belemnites*.

Chikkim shales.

In spite of careful search no fossils were found in the Chikkim shales.

HUNDES AND RUPSHU.

The route followed from Bashahr to Rupshu lay from Kurig, on the Para river, northwards over the hill-ranges to Parkyo, thence down again to the Para river near Kharak, where the river is with difficulty fordable, thence along the high ranges on the left side of the river, by the small village of Akse, to Chagya Sumdo. The southern portion of the area traversed consists entirely of mesozoic

rocks. Just north of Kurig the palæozoic rocks are replaced by lower trias beds, dipping to the north and north-east. These are followed by the upper trias, and, at and near the village of Parkyo, by jurassic beds, with Spiti shales. North and north-west of Parkyo, along the right side of the Para river, the Spiti shales are found on the higher parts of the mountains, much of the great range between Spiti and Hundes being composed of younger mesozoic beds. Near Kharak, only upper trias beds occur, and these continue for many miles to the north, but are gradually replaced by older beds, till, at the boundary between Hundes and Rupshu, palæozoic rocks predominate, the trias being found only in the higher parts of the ranges. To the north of Kharak, just beyond the village of Akse, the rocks begin to show signs of metamorphism, which becomes more and more marked towards the north. The greater part of southern Rupshu is, as stated by Stoliczka, composed of metamorphic schists, which being as a rule completely devoid of any trace of fossils, had not hitherto been assigned to any definite geological period. The recent traverse through Hundes, and the examination of portions of Rupshu hitherto unvisited, has now rendered this possible, and they have been found to include both trias and palæozoic beds. As a rule the whole of the carboniferous, permian and trias systems as far as the base of the upper triassic coral limestone, consist of a series of calcareous or siliceous schists, slates and quartzites. Above the coral limestone the upper trias and succeeding systems, which, however, are found only in the higher ranges, have been comparatively little altered, and can be identified by their fossils. The coral limestone forms a most valuable horizon, and throughout Southern Rupshu consists of a conspicuous white dolomite, in which the characteristic corals occur in abundance. Below this limestone, however, metamorphism has in almost all cases completely obliterated all traces of fossils, but the main characters of the rocks have been sufficiently retained to render possible a correlation of the various systems. This correlation, based at first on lithological grounds, has been borne out by the subsequent discovery of fossils.

Jurassic.

The highest beds seen are the jurassic limestones found on the Parang La, and near Tatang encamping ground in the Para valley: these are underlain by the usual limestones (Dachsteinkalk) followed to the north by the upper trias, with the characteristic coral limestone. Under

Trias.

these are limestones (often calcareous schists) and slates, representing the remainder of the trias; fossils (*Daonella*) have been found in these beds in the Pankpo lungba (lungba=stream , where the Daonella limestones and shales have been identified.

Below the trias in the Para river section, *i.e.*, along the Spiti-Korzok road, hard slates (probably representing the productus shales) contain distorted fossils, chiefly *Productus* sp., and *Spirifer musakheylensis*: below these slates are limestones and calcareous schists, part of which probably represent the calcareous (permian) sandstone, which occurs below the productus shales in Spiti; in the Phirse river these limestones and shales are full of crinoid stems. They are underlain by the characteristic conglomerates, followed by a great series of slates, schists and quartzites, which is well seen along the road between Narbo Sumdo and Korzok. A little to the south of Korzok, the siliceous beds are underlain by calcareous schists and crystalline limestones, as already recorded by Mr. Oldham.[1] Thence to a point about 2½ miles north of Korzok the road skirts the shore of the lake (Tso Moriri) along which the section is composed first of limestones and calc schists as at Korzok, underlain by limestones alternating with slates and quartzite, these in turn being underlain by more limestones. In this lowest series of limestones a bed was found containing remains of corals, strongly resembling a coral band which occurs near the middle of the upper silurian limestones of Spiti and Bashahr.

Below these limestones are slates or schists, gradually becoming garnetiferous, then felspathic, and passing gradually downwards through thin-bedded gneisses into the great system of gneiss and quartz-schist, which forms the precipitous ridge running from the head of Tso Moriri towards the north-west.

There seems therefore little doubt that from the base of the trias down to this gneiss, the above sequence consists of the altered representatives of the permian, carboniferous, and upper silurian systems, as seen in Bashahr and lower Spiti, and it is possible that the underlying gneiss may represent the great quartzite series which occurs eleswhere below the upper silurian limestones and shales. Seen from a distance, the gneiss, which forms bold cliffs of a hard, apparently well-bedded rock, bears a striking resemblance to the

[1] Rec., G. S. I., vol. XXI.

silurian quartzite, but on closer examination it is found to consist of alternating beds of gneiss and partly schist.

The gneiss, which is composed of quartz, orthoclase, muscovite and schörl, with very fine "*augen*" structure, has a distinctly bedded appearance, the "beds" which are about two feet thick being perfectly even and continuous, while the intercalated bands of quartz schist intensify the sedimentary appearance of the system. Unfortunately the time available did not allow of anything more than a cursory examination, and the base of the series not being exposed, it is impossible to refer it at present to any known system. It is probable that a continuation of the survey towards the north-west would throw some light on the question, as in that direction the beds appear to be less metamorphosed than in the neighbourhood of Tso Moriri, where intrusions of granite and of basic igneous rock are numerous.

IGNEOUS ROCKS.

Granite.

From the great granite mass at the head of the Sutlej valley in Kanaur, an arm runs almost continuously through the mountains lying to the north of the Para river in Hundes, into, and through Hanle and southern Rupshu. The beds traversed are partly of triassic, chiefly of carboniferous age. In southern Rupshu the essential minerals of the granite are quartz, orthoclase, biotite and a little muscovite, and the rock exactly resembles the granite of the Chandra valley between Spiti and Kulu, where, however, garnet occurs as an accessory mineral, and bands of coarse pegmatite with muscovite are very common.

Basic intrusion.

Basic rocks are numerous in Rupshu, where they are found intruded into the trias and carboniferous beds, and also into the Tso Moriri gneiss. They appear on a cursory examination to fall into two groups, a garnetiferous and a non-garnetiferous. The former are found in the gneiss, while the latter—chiefly composed of basalts and dolerites—occur among the trias and carboniferous beds. Want of time unfortunately precluded more than a very rapid examination of these rocks, and it is impossible to say whether the two groups have each a distinct origin; but the fact that all the intrusive rocks found in the gneiss contained garnets, while no trace of garnets could be

found among the intrusives occurring in the trias and carboniferous beds, make it seem possible that the difference may be due to the rock into which they have been intruded. But the evidence being merely negative no conclusion can safely be drawn.

ECONOMIC MINERALS.

Gypsum.—In addition to the localities already recorded by Mallet, gypsum occurs in large quantities in the upper beds of the limestone series on the ridge between the Lipak and Yulang (Yalung) rivers in Bashahr, and in the upper Gyundi valley in Spiti.

Gold.—At Chagya Sumdo on the Rupshu-Hundes border several pits have been sunk in the sub-recent deposits on the left bank of the Para river. Alluvial gold is said to have been obtained here in small quantities by the Tibetans, but the mines have not been worked for some fifteen or sixteen years. I washed a few pounds of material from the neighbouring stream but found no gold.

Stratigraphical notes *on the* Mesozoic rocks *of* Spiti, *by* DR. A. von KRAFFT, *Geological Survey of India.*

• The following is a preliminary account of the triassic rocks of Spiti. It embodies the stratigraphical results obtained by Mr. Hayden and myself during the summer of 1899, as well as the results of an examination of our collections. The largest number of the lower trias cephalopoda, recently collected in Spiti, has been described and worked out in full detail. The rest of the collections were examined as far as they appeared to be of stratigraphical importance.

The trias has been studied by me especially in the sections near Lilang on the Lingti river.

Lower trias. Sequence at Lilang. The lower-triassic sequence seen about 1½ miles north of Lilang on the left bank of the Lingti river, is as follows:—

(1) The Otoceras beds begin with a rusty brown, ferruginous layer of 1 to 5 inches in thickness, which has yielded only one badly preserved specimen, probably belonging to the genus

Ophiceras.

Then follows a sandy brown weathering limestone of 1 foot 7 inches, without fossils, overlaid by

(2) a limestone bed of 1 foot 5 inches, which most likely represents the "Main layer of *Otoceras woodwardi*" of the Shalshal cliff section (Pal. Indica, ser. XV, vol. II, pt. 1, p. 3). This bed is full of *Ophiceras sakuntala*, Dien., and other species of *Ophiceras*; it further contains

Meckoceras varaha, Dien.
„ *cf. boreale*, Dien.
„ nova sp. (two different species).
Danubites radians, Waag. var.
Pseudomonotis griesbachi, Bitt.

Otoceras has not been found in this bed at Lilang. It appears to be very rare in Spiti.

(3) Then follows a series of thin, black, concretionary limestone beds, alternating with thin shaly layers, together 3 feet thick. The prominent genus in these beds is *Meekoceras.* The species represented are—

Meekoceras varaha, Dien.
„ *cf. Hodgsoni*, Dien.

as well as seven new species, one of which is already present in bed 2 (see above). Of the six other new *Meekoceras*, one represents the group of smooth forms classified by Prof. Waagen with his genus *Gyronites*, although it is not perfectly identical with any of the Salt Range species. Another new species is allied—although not very closely—to "*Aspidites*" *discus*, Waag., from the middle ceratite

sandstone. A third is no doubt the direct ancestor of "*Aspidites*" *superbus*, Waag., occurring in the upper division of the lower trias of the Himalayas ("Subrobustus beds," Diener [1]) and in the upper region of the ceratite sandstones of the Salt Range.

As to the rest of the new species of *Meekoceras* no affinities to described forms can be recognized.

Besides these new species there must be mentioned a form very close allied to the Aictic "*Xenodiscus schmidti*, E. v. Mojs. (Arktische Triasfaunen, pl. xi, fig. 11) and a form most probably identical with *Meekoceras pulchrum*, Waag., from the ceratite marls of the Salt Range. There have further to be recorded—

Proptychites ammonoides, Waag.
„ *sp. aff. latifimbriato*, Waag.
„ *Markhami*, Dien.
Clypites nova sp.
Nautilus cf. brahmanicus, Griesb.

(4) The beds with *Meekoceras*, *Proptychites*, etc., are overlaid by shales, 10 inches in thickness, followed by grey, shaly limestones, 7 inches, with a few fossils, which in their preservation are exactly like those of the upper division of the lower trias. No determinable ammonites have been obtained, one fragment, however, probably belonging to *Flemingites*, another apparently to *Clipites*. Higher up follow brown weathering limestones, with very thin shaly partings without fossils. The whole thickness of the beds between the topmost Otoceras beds (3 above) and the limestones with *Hedenstrœmia mojsisovicsi*, Dien., etc., (below), amounts to 4 feet 8 inches. Nothing definite can be said as to whether those few beds belong palæontologically to the overlying series, as might be supposed from their lithological aspect.

•(5) The upper division of the lower trias is represented by a nodular limestone with very thin shaly partings, altogether 5 feet 7 inches thick. At Lilang ammonites are rather scarce and only the following few forms can be mentioned:—

Danubites nivalis, Dien.
„ *cf. ellipticus*, Dien.
Hedenstrœmia mojsisovicsi, Dien.

[1] For reasons to be given below, the term "Subrobustus beds" is no longer appropriate.

Flemingites cf. sp. ind. ex. aff. trilobato, Dien.
Pseudosageceras[1] nov. sp.

(6) In the following group of beds, of 30 feet thickness, which consists of grey shaly limestones and grey shales, alternating very regularly, fossils are extremely rare, and very badly preserved. The series must, however, be included in the upper division of the lower trias.

(7) The next series consists of a nodular limestone of 60 feet thickness, again very poor in fossils. It most probably belongs, at least partly, to the lower muschelkalk. The nodular limestone is overlaid by black limestones, containing the lower muschelkalk cephalopod fauna, described by Prof. Diener from the Chitichun area.

Comparison with Painkhanda (Shalshal cliff section).

The Otoceras beds are in Spiti much thinner than in Painkhanda.[2] The thickness of unfossiliferous beds between both divisions of the lower trias is very inconsiderable in Spiti, as limestones, very rich in *Meekoceras* are present between the "main layer of *Otoceras woodwardi*" and the upper division of the lower trias. The lower trias is separated from the fossiliferous lower muschelkalk by a thick nodular limestone, probably of lower muschelkalk age, which is not recorded from other parts of the central Himalayas.

Correlation with Salt Range.

Prof. Diener correlated the "main layer of *Otoceras woodwardi*" with the unfossiliferous shales and sandstones at the base of the lower ceratite limestone of the Salt Range. At the same time he considers the unfossiliferous beds, present in the middle of the lower trias of Painkhanda, equivalent to the lower ceratite limestone and the ceratite marls.

The researches in Spiti have led to a different result. As stated above, there is only a very inconsiderable thickness of practically unfossiliferous beds between the two divisions of the lower trias. Therefore these cannot possibly be of very different age. Moreover, palæontological evidence tells against Prof. Diener's correlation. The question will only be discussed very shortly here, but I hope to be able before long to give a full palæontological account of

[1] The genus *Pseudosageceras*, created by Prof. Diener, had so far only been known from Eastern Siberia (Mémoirs du Comité Géologique St. Petersburg, vol. XII, No. 3, 1895).

[2] See Griesbach, Mem. XXIII, pp. 144 to 147, Diener, Denkschriften d. k. Akademie der Wissenschaften, Vienna, 1895, p. 582, and Pal. Ind., l. c., p. 3.

the fauna of the lower trias of Spiti, and its relation to the lower trias of the Salt Range.

For the present the following might be mentioned:—

Several ammonites recently collected from the otoceras beds of Spiti are either identical with, or very closely allied to forms from the ceratite marls of the Salt Range, *viz.*:—

Proptychites ammonoides, Waag.
„ *sp. aff. latifim briattus*, Waag.
Meekoceras cf. pulchrum, Waag.

Here also *Meekoceras varaha*, Dien., has to be mentioned, which proved to be of closer affinity to "*kingites*" *lens*, Waag., of the ceratite marls, than was hitherto admitted by Prof. Dien.[1]

The following three species are identical with, or very intimately related to forms described from the lower region of the ceratite sandstone of the Salt Range, *viz.*:—

Danubites radians, Waag. sp.
„ *rotula*, Waag. sp.
Meekoceras aff. radiosum, Waag.

The specimen mentioned above as *Danubites radians*, Waagen, was recorded in last year's General Report as a new species, because it differs slightly from *D. radians* by having a somewhat flattened external part. A closer examination has, however, convinced me that it cannot specifically be separated from the Salt Range species. A probably older variety of this species, with very sharp marginal edges occurs at Lilang in a bed, which I believe to be equivalent to the main layer of "*Otoceras woodwardi*" of the Shalshal cliff section.

The palæontological evidence recorded above leads to the conclusion that the Otoceras beds are equivalent to the ceratite marls, and the lower ceratite sandstones of the Salt Range.

So far there is no decisive proof that the lower ceratite limestone is also represented in the Otoceras beds, although this is very probable for stratigraphical reasons. This is also indicated by certain faunistic affinities already recognized by Professor Diener (Pal. Ind., l. c., p. 176).

[1] Pal. Ind., Ser. XV, Vol. II, Pt. 1, p. 144.

The upper division of the lower trias has been correlated by Professor Diener with the whole ceratite sandstones of the Salt Range.[1] From what has been said above, it appears much more probable that the upper division of the lower trias of the Himalayas corresponds only to the two higher divisions of the ceratite sandstones, *viz.*, the Stachella beds and the *Flemingites flemingianus* beds. This also agrees better with Professor Diener's own results. Of the eight species from the upper part of the lower trias, which he mentions as being either intimately connected or probably identical with Salt Range species, he refers five to forms occurring in the middle and upper stage of the ceratite sandstones. He compares one with a species of the passage beds between the ceratite sandstones and the upper ceratite limestone, another to a species of the upper ceratite limestone. Only a single species is referred to a form known from the lower ceratite sandstones.[2]

The lower trias of the Salt Range and the Himalayas will therefore have to be correlated as follows:—

	Salt Range.	Himalayas.
Ceratite sandstones	Fl. flemingianus beds. Stachella beds. Lower stage of C. S.	Upper stage of ower trias.
	Ceratite marls Lower ceratite limestone	Otoceras beds.

Lower Muschelkalk. Fauna of the "Middlemiss crag" of Hundes discovered in Spiti.

One of the most interesting results of the stratigraphical researches in Spiti consists undoubtedly in the discovery in several localities of the lower muschelkalk cephalopod fauna, which was described by Professor Diener chiefly from the eastern slope of the limestone crag Chitichun No. 1 north-west of Lochambelkichak encamping ground in Hundes.[3]

This fauna was discovered by Mr. Middlemiss in a few blocks of red limestone, imbedded in Spiti shales, under conditions which did not allow of its stratigraphical position being ascertained. The fossils were chiefly derived from red crinoid limestone layers, intercalated in red, and red and white coloured limestone. No stratigraphical evidence being available, the age of this fauna had to be decided by its fossils contents only. The result arrived at by Professor Diener was, that it must belong to the lower muschelkalk.

[1] Pal. Ind., Ser. XV, Vol. II, Pt. 1, l. c. p. 177.
[2] Pal. Ind., Ser. XV, Vol. II, Pt. 1, l. c. pp. 175, 177 and Waagen, Fossils of the ceratite formation.
[3] Pal. Ind., Ser. XV, Vol. II, Pt. 2, pp. 101 to 108, Pl. XXIX to XXXI.

This fauna was found in Spiti at the base of the beds with *Spiriferina stracheyi*. Thus the view expressed by Professor Diener as to their age is proved to be correct. The limestone in which the fossils are imbedded is of a character different from that of the crags of Chitichun, being black, very hard and tough limestone.

We have seen above that the lower trias ends at Lilang with a nodular limestone of 60 feet thickness, which in all probability belongs partly to the lower muschelkalk. On top of this limestone follow:—

1. Six thin layers of hard, grey, partly concretionary limestone, together of 3 feet 2 inches thickness, which yielded no fossils.
2. This sequence is again overlaid by a band of hard, dark grey, very tough limestone, only 4 inch thick, which yielded a comparatively large number of ammonites. Commonest amongst them is a new species of—

Hungarites,

distinguished by very indistinct marginal edges. Another species, which is rather common, though obtainable in fragments only, is

Ceratites subrobustus, Mojs.

The specimens are perfectly identical with Professor Diener's type specimen as far as their sutures are concerned. They differ somewhat in sculpture, but the differences are not more considerable than between the specimen from Rimkin Paiar and the figures in Mojsisovics's "Arktische Trias Fauna."

The genus *Monophyllites* also plays an important rôle, and most of the species may be identified with species from Chitichun, or are closely related to forms described from Tibet. They are the following:—

Monophyllites confucii, Dien.
" *pitamaha* "
" *aff. Kingi.* "
" " *hara.* "
" *sp. group of M. Suessi*, Mojs.

Another characteristic and common species of these beds is

Sibirites prahlada, Dien.

described from the beds with *Spiriferina stracheyi*, Salter (see below). Besides this, there occur—

Gymnites ugra, Dien.
Danubites kansa, Dien.

both known from Chitichun, and a new species of

Prosphingites.

3. On top of this thin band with ammonites of lower muschelkalk age, lies a thin limestone bed (3 inch) with a fragment of *Spiriferina sp.* and

4. Immediately overlying the latter is a bed of 4 inches, with—

Spiriferina stracheyi, Salter.
Spirigera (*Athyris*) *stoliczkai*, Bitt.
Terebratula (*Dielasma*) *himalayana*, Bitt.
Rhynchonella mutabilis, Stol.

and other brachiopoda.

5. Two grey, concretionary limestone beds, 3 inches each, with brachiopoda, which have not yet been specifically determined in detail, and

6. Two beds of grey limestone, together of 16 inches, both containing

Xenaspis, nov. sp.

and a species of *Ceratites*, very similar to *Ceratites ravana*, Dien.

7. Immediately above this bed follows the well known Himalayan upper muschelkalk, with its rich fauna of *cephalopoda*. Shales are everywhere intercalated between the limestones, but decrease more and more in thickness towards the top.

This same limestone is *in situ* at also several other localities, *viz.*, 2 miles below Tangachenmo encamping ground, Gyundi river and in the Thanam valley; north-west of Lilang on the right bank of the Lingti river. At Muth a very good specimen of *Ceratites subrobustus* was found in a shaly layer in the immediate vicinity of (probably below) the beds with *Spiriferina stracheyi.*

From the Gyundi river there have to be mentioned—

Danubites kansa, Dien.
Gymnites ugra, Dien.

and several new species of *Gymnites* and *Ceratites.*

The ammonites collected north-west of Lilang are—

Ceratites subrobustus, Mojs.
Sibirites prahlada, Dien.
Monophyllites pitamaha, Dien.
" *aff. hara.*, Dien.
" " *kingi.*, Dien.
" *nov. sp. group of Monoph. Suessi*, Mojs.
" *Hungarites nov.* sp.

The small collection from the Thanam valley has not been examined in detail, but the presence of *Monophyllites* was ascertained.

Term "Subrobustus beds" no longer appropriate.

Prof. Diener divided the lower trias into two stages. He named the upper one "Subrobustus beds," as he obtained from its topmost bed[1] *Ceratites subrobustus* along with *Flemingites rohilla*.[2] The term "subrobustus beds" is, however, no longer appropriate, because *Ceratites subrobustus* occurs also higher up in the lower muschelkalk. This term had therefore best be discarded altogether as otherwise it might lead to misinterpretation.

"Horizon of Sibirites prahlada," Dien., not identical with the beds with Spiriferina stracheyi, Salter.

Sibirites prahlada, Dien., was recorded by Professor Diener to occur in the limestones with *Spiriferina stracheyi*. Consequently these brachiopod-beds were termed the "horizon of *Sibirites prahlada*.[3] This is not in accordance with my own observations, as I found *Sibirites prahlada* in beds underlying, but never in the limestone with *Spiriferina stracheyi* (see above). Professor Diener recently informed me by letter, that he had not collected *Spiriferina stracheyi* along with *Sibirites prahlada*. In the Shalshall cliff section, where he found *Sibirites prahlada*, no brachiopoda were found with it, while the brachiopoda mentioned by him were derived from a second locality further down the valley.

Thus there is no proof that *Sibirites prahlada* and *Spiriferina stracheyi* occur together, and we have to distinguish between cephalopod beds with ammonites of lower muschelkalk age and the

[1] Pal. Ind., Ser. XV, vol. II, pt. 1, p. 22.

[2] Communicated by letter.

[3] Pal. Ind., Ser. XV, Vol. II, pt. I, pp. 3 and 5, Denkschriften d. k. Akad. d. Wissenschaften, Vienna, 1895, p. 571.

brachiopod beds with *Spiriferina stracheyi*, in which so far no ammonites have been discovered.

Above the muschelkalk follows a group of limestones, which can be subdivided into :—

		feet.
Upper Carnic stage.	4. Hard, black, splintery limestone, somewhat bituminous, with calcite veins, weathering greyish brown, intercalated with shaly limestones in layers of one to three feet.— *Halobia cf. comata*, Bitt. " *cf. fascigera* " Representing part of the "Horizon of *Halobia comata*," Bitt.	111
	3. Black limestones as 4, intercalated with shales. Very large *Arcestes* sp.	25
Lower Ladinic stage.	2. Hard, black limestone as 4. *Daonella cf. commeli*, Waag. . . .	145
	1. Series of thin-bedded, black, shaly limestones and earthy shales, with some hard, black, brown weathering limestone beds . . .	160
	Towards the base rich in Cephalopoda (see below). *Daonella indica*, Bitt. " *commeli*, Waag.	

Horizon of *Daonella indica*, Bitt.

The most important of these four stages is the lowest one. This will have to be dealt with in detail since our researches have led to an entirely different result as to the age of this stage.

Professor Diener observed a crinoid limestone (Traumatocrinus limestone) in the Shalshal cliff section above the upper muschelkalk, from which he collected a number of ammonites which Mojsisovics declares to belong to his "Aonoides zone." Thence these observers assume that the upper muschelkalk is directly overlaid by deposits of upper carnic age, and also they believe that the ladinic and lower carnic stages are absent. It is very important to emphasize that this assumption of a break in this section is by no means supported by the geological evidence. Professor Diener himself, when examining the Traumatocrinus limestone, took it to be a division of the muschelkalk

"as it appeared to be perfectly conformable upon the Ptychites beds and to be stratigraphically intimately connected with them." [1]

No break in the succession of triassic beds in Spiti.

Representation of ladinic deposits fully ascertained.

In Spiti we have observed nothing which could be interpreted as a break in the sequence of triassic beds. Moreover the examination of the fossils collected from the muschelkalk and its overlying beds, has proved with certainty that such a break cannot possibly exist. The material collected in various localities has been worked out sufficiently in detail to decide this question.

There are altogether four points which prove that ladinic deposits do exist in Spiti.

a. Four species of ammonites and one of *Spirigera* are common to both the upper muschelkalk and the beds with *Daonella indica*, *viz.*,—

Proarcestes bicinctus, E. v. Mojs.
Ptychites gerardi, Blanf.
Hungarites nitiensis, E. v. Mojs.
" *nov. sp.*
Spirifera hunica, Bitt.

Proarcestes bicinctus has been described from the upper muschelkalk of Spiti. Last year it was collected by us at Raga in Spiti, from a limestone bed with *Monophyllites* sp. ind. group of *M. sphærophyllus*, *Ptychites gerardi* and *Ptychites asura*, Dien. The same species was also obtained at Ranna in the Thanam valley, and in another locality in the Thanam valley by Mr. Hayden, and south-east of Muth by us both. In all these last mentioned localities it was found to be abundant in the topmost bed of the upper muschelkalk, being associated with *Sturia Sansovinii*, Mojs., *Proarcestes balfouri*, Opp., *Ptychites gerardi*, Blanf., and other characteristic species of the upper muschelkalk.

But *Proarcestes bicinctus* is also quite as common in the beds with *Daonella indica*, Bitt. I have collected numerous specimens from the beds north of Po.

Ptychites Gerardi, Blanf., has long been known as a typical fossil of the Himalayan muschelkalk. However, this species is not confined to the muschelkalk, but, like *Proarcestes bicinctus*, reaches up

[1] Denkschriften der k. Akademie der Wissenschaften, Vienna, 1895, p. 547. Pal. Ind., Ser. XV, Vol. III, Pt. 1, pp. 127, 128, and 135.

into the beds with *Daonella indica.* E. v. Mojsisovics in his recent Memoir on the cephalopoda of the upper trias of the Himalayas (Pal. Indica, Ser. XV, Vol. III, Pt. 1, p. 117, Pl. XIX, figs. 8 and 9) described from the black limestone, facing the Ralphu glacier, regarded as equivalent to the *Traumatocrinus* limestone of Rimkin Paiar, a species which he names *Ptychites posthumus.* This species in my opinion is identical with the well-known muschelkalk species *Ptychites gerardi,* Blanf. This is clear from the shape of the shell and from the suture lines. The latter show the same semicircular arrangement as in *Ptychites Gerardi,* and also a bipartite second lateral, and first auxiliary saddle. It must be remarked that the figure of the sutural line of *Ptychites posthumus* in E. v. Mojsisovics's Memoir is not quite correct, as the median incision of the second lateral saddle is not represented deep enough, while the branches of the first auxiliary saddle are drawn too slender. In reality these two saddles are of almost equal size in the type-specimen, which I have re-examined. I collected two small specimens of *Ptychites* identical with *Ptychites posthumus* = *Ptychites Gerardi,* Blanf., from the beds with *Daonella indica* north of Po.

Hungarites nitiensis, Mojs., had so far only been known from the crinoid limestone of Rimkin Paiar, and from beds of unknown age of the Niti pass. This species was found by Mr. Hayden in the Thanam valley, in beds immediately overlying the muschelkalk. But we also collected it from the muschelkalk of Kaga. The identity of the species could be fully established, thanks to the fortunate fact that I was able to compare it with the type-specimen from Rimkin Paiar. The *Hungarites* nov. spec. mentioned above, is a very characteristic species, having transverse folds of a most distinct falciform bend as in *Harpoceras,* but it bears no resemblance to any of the Alpine species. It occurs in the muschelkalk of Kaga, in the topmost bed of the muschelkalk at Banna encamping ground, Thanam valley, and in the ladinic beds immediately overlying the topmost muschelkalk in another locality in the Thanam valley (collected by Mr. Hayden).

Spirigera hunica, Bitt., was described from the beds with *Daonella indica* from the Shal-Shal section and other localities. It has also been found in Spiti (north of Po, west of Lilang) in these beds, but the same species occurs in the topmost beds of the muschelkalk at Banna encamping ground and south-east of Muth.

Besides these five species, ranging from the muschelkalk into the beds with *Daonella indica*, *Arpadites stracheyi*, Mojs., has to be dealt with.

This form is described and figured on page 58, of E. v. Mojsisovics's recent publication, from a plaster cast of the original specimen collected by General Sir Richard Strachey on the Niti pass. It had formerly been figured by Salter and Blanford in the Palæontology of Niti, pl. 8, fig. 3. E. v. Mojsisovics attributed this species to the ladinic stage, assuming that it was derived from beds homotarial to the Traumatocrinus limestone of Rimkin Paiar. On the topmost bed of the muschelkalk at Banna encamping ground Mr. Hayden collected several specimens of an *Arpadites*, which in my opinion are identical with *Arpadites stracheyi*, Mojs. They most strikingly recall the species from the Niti pass in general shape, especially by their obliquely elliptical outline. The external part agrees perfectly with the description given by Dr. v. Mojsisovics, as the marginal edges are not yet visible at the beginning of the last volution, and become more and more distinct towards the anterior termination. Small, slightly curved, transverse folds are visible on the anterior half of the last whorl. The sutures on the whole correspond to the illustration in the Palæontology of Niti, pl. 8, fig. 3 d. There is a very low siphonal tubercle (though slightly higher than in the figure), each branch of the siphonal lobe terminating in one point. The lateral lobes do not correspond to the figure in the minor details, their dentation being deeper and not quite as numerous. The saddles are more slender than in Salter's figure. But the number of lobes and saddles agrees with the figure, and as for the differences mentioned, they might well be due to incorrect drawing. The sides of the chambered part of the Spiti specimens are covered with short, rather strong, radial folds, which only become weaker and falciform towards the anterior termination. Such folds are not visible in the figure of the plaster cast in Mojsisovics's Memoir, but they are indicated in Salter's figure pl. 8, fig. 3a. Owing to the insufficient knowledge of the specific characters of *Arpadites stracheyi*, the identity of the Spiti specimens with those from the Niti pass cannot be fully ascertained, but it is at least highly probable that this species also occurs in the uppermost beds of the muschelkalk.

b. Besides the forms, which are identical with upper muschelkalk species, one new species, which is closely allied to a muschelkalk

species, must be mentioned from the beds with *Daonella indica*, *viz.:*

Ceratites nov. sp. aff. Cer. Himalayanus, Blanf.—It is only distinguished by more complicated sutures and a wider umbilicus, as the involution takes place outside the spiral row of lateral tubercles (north of Po and Thanam valley).

c. Four species recently collected from the beds with *Daonella indica* are either identical with, or closely allied to European forms from deposits of ladinic age, namely:—

Gymnites ecki, E. v. Mojs.
Hungarites aff. mojsisovicsi, Boeckh.
Trachyceras archelaus, Laube.
Trachyceras aff. ladinum, E. v. Mojs.

Daonella Lommeli, Wiss., collected years ago by Mr. Griesbach south-east of Muth, must be added to these forms. The occurrence of this species has already been pointed out by Dr. A. Bittner as an indication that ladinic deposits might be present in the trias of Spiti.[1] As to *Gymnites ecki*, E. v. Mojs., although the sutures could not be compared in detail with those of European specimens, the specific identity may be said to be indisputable; north of Po.

Hungarites aff. mojsisovicsi, Boeckh, is very similar to the European form, but here again the sutures cannot be compared in detail. The only specimen obtained north of Po is smaller than the two specimens figured in E. v. Mojsisovics's "Cephalopoden der Mediterranen Triasprovinz."[1] It has a diameter of 46 mm. and is distinguished from the Hungarian forms by a less prominent median keel and a slightly more pronounced falciform bend of the transverse folds.

The forms mentioned as *Trachyceras ladinum*, E. v. Mojs., cannot be distinguished from the Alpine species, corresponding as they do completely in the arrangement and number of the spiral rows of tubercles. The marginal thorns are perhaps somewhat more pronounced, but the difference is too slight to be of any importance. Found north of Po.

Trachyceras aff. archelaus, Laube, is very closely allied to the European species, to which it corresponds in its general shape and in the number of spiral rows of tubercles. Thanam valley,

[1] Jahrbuch der Geol. Reichsanst., Vienna, 1899, p. 695.

Colln. Hayden; North of Po.

Daonella lommeli, Wiss., had, as above mentioned, already been known from Spiti. We found *Daonella lommeli* even more common than *Daonella indica* and obtained a considerable number of specimens from various localities.

d. Besides the palæontological evidence recorded above, the following fact tells against the assumption of a break in the succession of beds. In several sections in Spiti we collected the true *Joannites cymbiformis*, Wulf., along with a species closely related to *Trachyceras aonoides* in beds, situated from 400 to 450 feet above the upper muschelkalk (see below).

This will suffice to show that, so far as Spiti is concerned, there is no doubt that the ladinic stage is well developed. Dr. Bittner was therefore perfectly right in this point, although his surmise that the ladinic stage might be represented in Spiti was founded only on the occurrence of *Daonella lommeli.* In Spiti the passage from the muschelkalk into the ladinic is palæontologically such a gradual one, that, were it not for a lithological change, it would be difficult to define the horizons.

We have now to consider whether the arguments brought forward in favour of a break in the Shal-Shal cliff section hold good.

Age of the Traumatocrinus limestone of Rimkin Paiar.

The Traumatocrinus limestone of Rimkin Paiar has been looked upon as upper ladinic, principally because the following two species of ammonites occur in it:

Trachyceras tibeticum, E. v. Mojs.
"*Joannites aff. cymbiformis*, Wulf."

The accuracy of the determination of the latter species is extremely doubtful. Of the two specimens, which chiefly served for description, the smaller one (pl. XX, fig. 3, E. v. Mojsisovics, Pal. Ind., Ser. XV, vol. III, pt. 1) has only six saddles outside the umbilical margin, while *Joannites cymbiformis* has eight. The second and the larger specimen, the sutures of which have been figured on pl. XX, fig. 4, l. c., is distinguished from *Joannites cymbiformis*, Wulf., by the entire absence of varices. This fact was noticed, but apparently deemed unimportant by E. v. Mojsisovics (page 101 l. c.). Species similar to *Joannites cymbiformis* occur already in the muschelkalk. At Kaga two small

specimens were collected by Mr. Hayden in 1898, and mentioned in last year's Annual Report, page 16, as *Joannites aff. diffissus*, Hauer. But Prof. Diener, to whom they had been sent for examination, determined them as probably *Joannites cymbiformis*, Wulf. It is therefore quite natural that similar forms should also be present in the ladinic beds. However, it must be borne in mind that none of the muschelkalk and ladinic types are actually identical with the true *Joannites cymbiformis*, which species, as already mentioned, occurs from 400 to 450 feet above the muschelkalk.

Trachyceras tibeticum, E. v. Mojs., which has not been found yet in Spiti, is no doubt closely allied to the carnic *Trachyceras austriacum*, as has been stated by E. v. Mojsisovics. It differs in having simpler sutures and in the characters of the external part. Dr. v. Mojsisovics himself considers *Trach. tibeticum* a new species, or if not, a variety of the Alpine *Trach. austriacum*. This being the case, I do not see why its occurrence in the Traumatocrinus limestone should not be explained more naturally by assuming that an older variety of the carnic *Trachyceras austriacum* of Europe appears in the Himalayas already in ladinic deposits.

Certainly, the evidence brought forward in favour of the correlation of the Traumatocrinus limestone with the upper carnic of the Alps is not a convincing one, and there is so far, not sufficient reason for supposing that in Painkhanda the ladinic stage, so well developed in Spiti, should be wanting.

As to the remainder of the argument, subdivided above into four different parts, the following may be noted.

Thickness of ladinic stage.

The hard, black, splintery limestones No. 2 yielded among other fossils a fragment of *Daonella cf. lommeli*, Wiss., derived from the base of the upper third of this limestone mass. I therefore include the black limestone No. 2 with the ladinic. This stage thus has a thickness of approximately 300 feet.

At Kuling we discovered a great many specimens of *Daonella lommeli* in shaly beds alternating with dark, splintery limestones. Among these there are unusually large specimens, measuring about 100 mm. from the umbo to the opposite margin of the shell. As the beds, from which we collected, were vertical, their stratigraphical position could not be ascertained. My opinion is that they belong either to No. 1 or No. 2 of the above sub-division. There is certainly

no reason to suppose these beds equivalent to No. 3 or No. 4, as in spite of careful search in undisturbed beds opposite Lilang I have never met with a *Daonella lommeli* higher up than in the upper third of series No. 2.

Horizon of Halobia comata, Bitt.

On the other hand series 4 yielded two specimens of *Halobia*, which should in all probability be referred to *Halobia fascigera*, Bitt., and *Halobia comata*, Bitt.

No. 4 therefore corresponds to part of the "horizon of *Halobia comata*," Bittner, which according to this author represents or at least includes the equivalents of the Alpine Lunz-Raibler beds.[1]

Above the series of black limestones, recorded above, thick grey, earthy shales, in which grey, shaly limestones of various thicknesses are intercalated throughout Spiti. The series is of so uniform a character, that it can hardly be subdivided, unless in a very detailed fashion. However the following three divisions may be distinguished—

3. Grey, shaly limestones, alternating with calcareous, earthy shales.
2. Thin-bedded, shaly grey limestones about 20 feet.
1. Grey earthy shales, with numerous thin shaly limestone beds.

The thickness of this series amounts to at least 500 feet, the thin-bedded limestone 2 keeping about the middle of the system.

As to fossil contents two fossiliferous horizons may be mentioned. The lower one situated at the very base of the series, lying immediately on the topmost hard splintery limestones referred to above. The upper fossiliferous horizon occurs in part 3 of this series and consists of limestones, rich in *brachipoda*, situated about 40 feet above the thin-bedded limestone No. 2. The lower fossil horizon is of considerable importance. Mr. Hayden first recognised that the grey, shaly beds at the base of this series contained specimens of *Trachyceras*, closely allied to *Trachyceras aonoides*, E. v. Mojs. His collections from these beds 4 miles west of Thabo in 1898 comprise the following species.[1]

Shales with Joannites cymbiformis, Wulf.

Joannites cymbiformis, Wulf. (3)
Hauerites nov. sp. (1)

[1] Pal Ind., Ser. XV, Vol. III, Part 2, p. 47 (in the press).

Trachyceras cf. aonoides, E. v. Mojs. (1)
" *nov. sp. aff. ariae*, E. v. Mojs. (1)
" *sp. ind.* (several fragments).

The only fossil of these collections, which could be identified with certainty, is *Joannites cymbiformis*, Wulf. As to *Trachyceras cf. aonoides*, it cannot be said to be perfectly identical with the European types, but so much is certain, that it resembles none of the European forms of *Trachyceras* as closely as it does *Trachyceras aonoides*.

As to last year's collections from the shales with *Joannites cymbiformis*, the following discoveries were made :—

1. Several fragments of a small *Trachyceras* which in sculpture and transverse section strongly recall such forms as *Trachyceras ariae*, E. v. Mojs. ("Gebirge um Hallstadt," pl. Clxxvi, fig. 3) or *Trachyceras griseldis* (l. c. pl. Clxxviii, fig. 1), collected at Banna encamping ground, Thanam valley, by Mr. Hayden.
2. Crushed specimens of *Trachyceras*, closely resembling in sculpture *Trachyceras aonoides* (north-north-west of Muth, Spiti, coll. Krafft, right bank of Lipak river, above Lipak encamping ground, coll. Hayden).
3. *Joannites cymbiformis*, Wulf (1 spec.) same locality. The specimen is entirely chambered and measures 80 mm. in diameter, the last volution being 43 mm. high. There are three varices on the last volution. Number of saddles outside the umbilical margin eight, corresponding to those of *Joannites cymbiformis*. This species was collected by Mr. Hayden above Lipak E. G.; fragments of *Joannites cf. cymbiformis* were obtained by him at Banna encamping ground; west of Lilang, and between Pomcrang and Mani.
4. *Drepanites* nov. sp. ind. 4 miles west of Thabo; coll. Krafft.
5. *Hauerites* nov. sp. (fragment) Banna encamping ground; colln. Hayden, resembling the Noric *Hauerites raristriatus*, E. v. Mojs., but differing in its sutural lines. This species was collected by Mr. Hayden 4 miles west of Thabo.

The second fossiliferous horizon of the system of grey beds was discovered north-north-west of Lilang. With the exception of one ammonite and some bivalves it yielded chiefly *Brachiopoda*. Of these only

Brachiopod beds.

Spiriferina shalshalensis, Bitt.
Rhynchonella lankana, Bitt., *and Discina* sp.

could be identified with species described from the trias of the Himalayas.[1] The bulk of the collections made, which comprise numerous well preserved specimens, belongs to species not recorded yet from the Himalayas. They have not yet been worked out in detail.

The only ammonite collected from this horizon is a small specimen very similar in its general shape, sculpture and the character of the external part, to the noric *Distichites goebli*, E. v. Mojs. (Gebirge um Hallstadt, pl. CXLIX), but distinguised by ceratitic sutures. The number of saddles and lobes is the same.

Above the series of shaly beds just referred to is a sequence of beds which still keeps up to a considerable extent the lithological character of the underlying beds, but is richer in intercalated limestone layers. This series may be said to consist chiefly of three kinds of strata, *viz*. (1) black, splintery, thin-bedded limestones, mostly concretionary and with brown dolomitic patches, (2) light grey, shaly limestones, (3) grey crumbling shales. These three kinds of deposits alternate very regularly and acquire a thickness of from 600 to 700 feet This series is not very rich in fossils, and those that are present are either badly crushed or otherwise insufficiently preserved. About the middle of the series occur large bivalves and very small *Brachiopoda*, which have not yet been worked out. Higher up, about 400 to 500 feet above the base of the series, a brown weathering, nodular limestone alternating with grey, crumbling shales, was observed, which has yielded cephalopoda of the genus *Tropites* and other genera. Unfortunately well preserved specimens are extremely rare. The collections recorded below were derived from the sections round Lilang and comprise the following species.

Nodular limestone with Tropites, etc.

[1] Bittner, Pal. Indica l. c.

Tropites cf. subbullatus, v. Hauer
(badly preserved specimens)

Tropites cf. discobullatus, E. v. Mojs.

The specimens are extremely like those on pl. CIV in E. v. Mojsisovics's Gebirge um Hallstadt. The sculpture on the external part of the last volution is identical with fig. 1 c, pl. CIV. The sutures differ slightly. Whether this form is identical with the *Tropites ind. cf. discobullatus*, described by Mojsisovics from Kalapani[1] is uncertain, the latter being too badly preserved for close comparison.

Tropites (*Paratropites*) *nov. sp.*
" *cf. fusobullatus*, E. v. Mojs.
" *cf. torquillus*, E. v. Mojs.
very closely allied to the European species.

Many indeterminable fragments of *Tropites.*

Juvavites aff. bacchus, E. v. Mojs.
" *sp. ind. cf. J. bacchus*, E. v. Mojs.

Sagenites sp. aff. crinaceus, E. v. Mojs.
" *n. sp. aff. herbichi*, E. v. Mojs.

Sandlingites n. sp. ind.

Sirenites n. sp. ind.

? *Heraclites* sp. ind.; two different species, resembling *Heraclites*, especially *Heraclites bellonii*, E. v. Mojs., in general shape and sculpture, but differing from *Heraclites* by ceratitic sutures.

Clydonautilus griesbachi, E. v. Mojs.

Nautilus sp., three different species.

There can be very little doubt that this limestone with *Tropites* corresponds to the Tropites limestone of Kalapani, which E. v. Mojsisovics considers to be homo-taxial to the subbullatus beds of Hallstadt. As the stratigraphical position of the Tropites limestone of Kalapani is not known exactly, it is of considerable importance that the position of the Tropites beds has been fully established nevertheless.

About 70 feet above the nodular limestone with *Tropites*, a few large specimens of *Parajuvavites* nov. sp. were collected from grey shaly limestones. These beds will have to be included in the

[1] Pal. Ind. l. c., p. 48, pl. XI, fig 7.

Tropites beds, as the same new species of *Parajuvavites* probably occurs in the latter[1] also.

"Zone of Clydonautilus griesbachi untenable."

Clydonautilus griesbachi—is, according to E. v. Mojsisovics the leading fossil of the "Hauerites beds". In Spiti these have been traced about 500 feet above the Tropites limestone (see below). I have never met with *Clydonautilus griesbachi* in any other horizon but the Tropites limestone, where I collected a good specimen west of Lilang. It appears that this species ranges through a considerable thickness of beds. The zone of *Clydonautilus griesbachi*' introduced by E. v. Mojsisovics to replace Diener's term *Hauerites beds*[2] is very probably untenable.

The uppermost beds of the series referred to above, gradually pass into a mass, chiefly of dolomitic limestone. At its base this consists of black, concretionary, hard limestone beds such as are found in the underlying beds. But it becomes greyer in colour and more and more dolomitic higher up, where it is very thickly bedded. The whole thickness of this limestone mass amounts to about 300 feet.

A few bivalves and brachiopods were collected from this limestone. These were sent for determination to Dr. Bittner, as they appeared to be allied to characteristic alpine forms. As no answer has so far arrived from him, I am unfortunately unable to give any particulars about these fossils.

According to Prof. Diener the Daonella beds, *viz.*, the whole thickness of deposits included between the upper muschelkalk and the Hauerites beds amounts in Painkhanada and Johar to 600 to 750 ft.[3] The beds which in Spiti correspond to Prof. Diener's Daonella beds are much thicker, amounting to nearly 2,000 feet, or roughly three times the thickness of the latter.

The thick, dolomitic limestone mass just referred to, is overlaid by a system, chiefly composed of brown weathering sandy and shaly limestones. In this series, which amounts to about 500 feet, grey crumbling shales, alternating with brown limestones also occur in the upper half. Black, splintery limestones are met with near the base. About the middle of the series occur brown flaggy

[1] Found loose in the Tropites beds, under conditions which make it very improbable that it should have rolled down from higher beds.

[2] Pal. Ind., Ser. XV, Vol. III, pt. I, p. 136.

[3] Denkschriften l. c., p. 582.

sandstones, showing beautiful false-bedding and with indistinct *plant* remains.

Beds with (?) Hauerites n.p. ind., E. v. Mojs.

Amongst the fossil contents the following may be mentioned. I collected a specimen of *Hauerites* near the base of the series, at Chabrang, in brown weathering sandy limestones. This appears to be identical with the ? *Hauerites n. f. ind.* the sutures of which have been figured in E. v. Mojsisovics's recent Memoir. Along with this species occurs a very large *Paratibetites*, closely allied to *Paratibetites tornquisti*, E. v. Mojs. It differs only slightly in the suture lines. Besides this, several specimens of *Hauerites*, differing in sutures from that mentioned above, *brachiopoda* and bivalves, *viz.*, *Mysidioptera* sp., *Avicula* sp., *Modiola* sp., *Anodontophora griesbachi*, Bitt., a species of considerable vertical distribution. (See below and Bittner Pal. Ind. l.c., p. 61.)

Beds with Juvavites, etc., equivalent to the Halorites beds, Dien.; faunistic difference.

Above the fossiliferous strata just described, beds with numerous cephalapoda occur in the upper half of the system in all the sections examined. These from their stratigraphical position, and also to a certain extent owing to their palæontological character, must be looked upon as the equivalents of the Halorites beds, Dien.

By far the most prominent genus of these beds is *Juvavites*. Specimens of this genus are fairly common throughout Spiti although nowhere abundant. Among the forms collected there are a few specimens belonging to the group of the 'continui' E. v. Mojsisovics and allied to *Juvavites ehrlichi*, E. v. Mojs.[1] Other specimens, also few in number, belong to the group of the "intermittentes" and "scissi," E. v. Mojsisovics. But by far the greatest number is characterized by ribs crossing the external part with little, if any interruption; they are at the same time very strongly bent forward, a feature which distinguishes these specimens from all the species known from the Hallstadt limestone. Apart from this they exhibit the characters of the "continui."

[1] The species is not identical with Griesbach's *Tropites Ehrlichi var. feistmanteli* nov. sp. Mem. XXIII, p. 142, described by E. v. Mojsisovics, l. c., p. 24, pl. VI., figs. 1, 2, 3 as *Parajuvavites feistmanteli*.

Besides forms belonging to the genus *Juvavites*, the following species have to be mentioned:

Paratibetites tornquisti, E. v. Mojs.
Tibetites cf. ryalli, E. v. Mojs.
Anatibetites nov. ?sp. aff. kelvini.

a very interesting species being distinguished from *Anatibetites kelvini* by incised saddles, while otherwise identical with it.

Clionites aff. hughesi, E. v. Mojs.
Dittmarites nov. sp.

differing from *Dittmarites hindei*, E. v. Mojs, by broader whorls and wider umabilicus,

Pinacoceras sp.
Phylloceras sp. ind.
Pleuronautilus sp. aff tibeticus, E. v. Mojs.

It is a very strange fact that not one of these species can be said to be perfectly indentical with forms described from the Bambanag section. The only species very closely allied to a described form is *Paratibetites tornquisti*, E. v. Mojs.

No Halorites discovered in Spiti.

It is also strange that not a single specimen of *Halorites* so common in the "Halorites beds" of the Bambanag cliff has been met with in Spiti. Neither is the genus *Parajuvavites* present in our collections, from the beds I am referring to, although a few specimens have been found lower down in beds which I included in the tropites beds (see above).

But for all that there can be little doubt that the beds with *Juvavites* must belong to pretty much the same horizon as the "Halorites beds," Diener. For they are overlaid by a coral limestone, with *Spiriferina griesbachi*, Bitt., which may safely be correlated with the "limestone with *Spiriferina griesbachi*" of the eastern Himalayas.

It appears from the above, that there is a remarkable faunistic difference between the "Halorites beds" of the more eastern Himalayas, and their equivalents in Spiti, for which so far no explanation can be given. The facies of these beds in Spiti is rather unfavourable for the preservation of fossils. This no doubt accounts for the comparative scarcity of the fauna.

As mentioned before, the beds with *Juvavites*, etc., are overlaid by a grey limestone mass of about 100 feet in thickness. This is a true organigenic limestone, being composed almost entirely of fossil remains, among which *corals* and *Bryozoa* (?) are predominant. Besides this there are a few brachiopoda belonging to the species—

Local limestone with Spiriferina griesbachi.

Spiriferina griesbachi, Bitt., and
(?) *Rhynchonella bambanagensis*, Bitt.

This limestone is no doubt equivalent to the "limestone with *Spiriferina griesbachi*," Dien.

The beds overlying the coral limestone are lithologically very similar to the beds below it. It is chiefly composed of brown-weathering, sandy, and shaly limestones, often dolomitic, with brown weathering sandstones, calcareous shales, and dark grey, hard limestones with brown dolomitic patches. The thickness of this series is about 300 feet. Palæontologically it is characterized by its richness in bivalves and brachiopoda, ammonites being extremely rare. The former must first of all be mentioned.

Beds with Monotis salinaria, Spiriferina griesbachi, etc., equivalent to the "Sagenites beds," Dien.

Monotis salinaria, Br.

The discovery of this characteristic bivalve, which now for the first time is recorded from the Himalayas, is due to Mr. Hayden. He found it to be abundant between Mani and the Pin river on the right bank of the Spiti river. Later on I traced it also in a section east, above Lilang, but it is by no means so common there as near Mani. The layer of *Monotis salinaria* is a light grey, somewhat shaly-limestone, situated east of Lilang about 200 feet above the coral limestone. It is particularly interesting to note that the mode of occurrence of *Monotis salinaria* is exactly the same in Spiti as in the Pamir, where Ferdinand Stoliczka collected the species north-east of Ak Tash, 4 miles west of the Neza-Tash pass.[1] Indeed hand-specimens from Spiti can scarcely be distinguished from those of Stoliczka's collections. Other fossils of this series are—

Anodontophora griesbachi, Bitt.
Spiriferina griesbachi, Bitt.

[1] *E. Suess. Zur* Stratigraphie Central-Asiens; Denkschriften der k. Akademie d. Wissenschaften, Vienna, 1894, p. 460.

Rhynchonella bambanagensis, Bitt.
Aulacothyris joharensis, Bitt.
Spirigera dieneri, Bitt.
Distichites nov. sp. (fragments.)

Within this series, *Spiriferina griesbachi* was found in beds about 30 to 50 feet higher than the layer with *Monotis salinaria*. In the former horizon the rest of the species above mentioned, except *Spirigera Dieneri*, also occur; only one specimen of this species was found north of the Manirang pass in a shaly bed, immediately above the coral limestone.

The specimens of *Spiriferina griesbachi* of this stage are distinguished from those of the coral limestone below, by their remarkable size. Bittner[1] has already drawn attention to the close resemblance of *Spiriferina griesbachi* to Stoliczka's *Spiriferina tibetica* and *altivaga*, described as carboniferous forms. He considers it probable that these three species are identical. This is no doubt the case. Stoliczka's specimens cannot have been collected from the carboniferous, as nowhere in the true carboniferous of Spiti was found a brachiopod similar to *Spiriferina griesbachi*. Moreover, nowhere within many miles of Kibber, where Stoliczka found loose specimens of *Spiriferina tibetica*, do carboniferous rocks occur. On the other hand north of Kibber, near the Parang Lá, Mr. Hayden observed the beds with *Spiriferina griesbachi*, so that doubtlessly Stoliczka's loose specimens had come from these beds.

The localities from which *Spiriferina griesbachi* have been obtained are very numerous, indeed in every section of upper Trias examined, the species was found to be abundant.

As to ammonites, only fragments, apparently belonging to the genus *Distichites*, have to be recorded. The genus *Sagenites* has not been traced in these beds. However, there can be no doubt that the series with *Monotis salinaria*, *Spiriferina griesbachi*, etc., corresponds to those beds of Painkhanda and Johar which have been termed "Sagenites beds" by Prof. Diener.

Series of quartzites, limestones and shales with Spiriferina griesbachi, Bitt., and Aulacothyris joharensis, Bitt.

The beds with *Monotis salinaria* and *Spiriferina griesbachi*, etc., are overlaid by a series, characterized by the occurrence of white and brown quartzites. It forms a most conspicuous horizon throughout Spiti, and is often perceptible at great

[1] Jahrbuch d. geol. Reichsanstalt, Vienna, 1899, p. 696.

distances as a white band. Generally three different layers of quartzite can be distinguished, separated from each other in the lower part by limestones, but towards the top black, shaly beds are intercalated. The system varies rather in character. It will suffice to mention the sequence as observed near Lilang which is as follows :—

6. Great thickness of black and grey, dolomitic limestone.
4. Thick, brown quartzite.
5. Black sandy shales, with *Aulacothyris joharensis*, Bitt., alternating with thin brown quartzite layers; over 100 feet.
3. Thin band of beautifully white quartzite.
2. Dark grey, hard limestone, sandy or dolomitic, with brown dolomitic patches, and strange markings, probably representing sections of ? *Megalodon* or ? *Dicerocardium*, with *Spiriferina griesbachi*, Bitt. *Lima serraticosta*, Bitt.; about 200 feet.
1. Brown quartzite, about 20 feet.

Spiriferina griesbachi and *Aulacothyris joharensis* reach up from the lower beds into this horizon.

Thick sequence of limestones, representing Dachsteinkalk, in part Rhaetic, Lias and Oolite.

The beds above the quartzite series are of a very uniform lithological character. They consist of dolomitic, black or grey, somewhat earthy limestones mostly in thin beds. These, although acquiring a thickness of roughly 2,300 feet, do not change to any remarkable extent lithologically. With reference to this, I must, however, mention that about 400 feet above the quartzite series a white, dolomitic band of about 30 feet in thickness was observed in several sections. Frequently in these limestones red, dolomitic bands occur. Near Gieumal I observed about 80 feet below the Spiti shales, a brown quartzite of about 10 feet thickness. This may correspond to the conglomerate mentioned by Mr. Griesbach[1] as forming a contact bed between his upper lias and the Spiti shales, north of the Niti pass. However, it must be emphatically remarked that no trace of an unconformability can be observed. There is every evidence that the passage from this limestone sequence into the Spiti shales is a perfectly gradual one.

[1] Mem. XXIII, p. 126.

The limestone series below the Spiti shales is throughout—except in the uppermost layers—extremely poor in fossils, and those present are generally badly preserved. For this reason, only a few data can be given.

Since this limestone mass is capped by the upper jurassic [1] Spiti shales, and since not the slightest trace of a break in the sedimentation can be discerned, the limestone mass must needs represent the uppermost dachsteinkalk, rhaetic, lias and oolite. This is, however, only proved by fossils as far as oolite and trias are concerned. Certain discoveries point to lias, but no rhaetic fossils have, so far, been recognized.

The following fossils can be recorded:—

Dachsteinkalk in part.

1. *Megalodon ladakhensis*, Bitt.[2], occurring at 50 feet above the quartzite series in a thick band almost entirely composed of *Megalodon*, at Hansi. This species was also collected by Mr. Hayden, Palang Buldur, Para river, Rupshu.
2. (?) *Spirigera Noetlingi*, Bitt., described in Bittner's recent Memoir "from beds of unknown age (presumably lias) from Nio-Sumdo in Karnag."

Lima cumaunica, Bitt.
,, *serraticosta*, Bitt.
Spiriferina nov. sp.

very similar to *Spiriferina griesbachi*, but without a median rib in the sinus of the large valve, and without a furrow in the lobe of the small valve.

All these forms were collected between 200 and 300 feet above the quartzite series at various localities.

3. *Gastropods* in bad preservation, among them a form, similar to *Naticopsis gradata*, Koken. About 400 feet above the quartzite series; east of Lilang.
4. Bivalves, chiefly *Pecten* and other genera, mostly preserved in casts, *corals*, etc., not yet worked out. Collected up to about 400 feet above the quartzite series.

Lias?

5. 800 to 900 feet above the quartzite series I collected between Gieumal and Chabrang a few very well preserved specimens of *Spiriferina*, which bear a

[1] Denkschriften d. k. Ak. d. Wissenschaften in Wien, 1895, p. 587.
[2] Palæontologia Indica l. c.

striking resemblance to *Spiriferina obtusa*, Opp., of the Hierlatz limestone of the eastern Alps (Geyer, Liasische Brachiopoden des Hierlatz, Abhandlungen d. geol. Reichsanstalt, Vienna, 1889, pl. VIII). Although I should not like to attach any vital importance to this discovery, it is of interest, connected with the following observation.

Kelloway.

6. About 1,000 feet above the layer in which *Spiriferina cf. obtusa*, Opp., was obtained, and 370 feet below the base of the Spiti shales, a very well preserved ammonite was collected in the section between Chabrang and Gieumal. This is closely allied to *Stephanoceras coronatum*, Brug. (Explanations de la Carte Géologique de France, Tome IV, 1878, pl. LIV, fig. 2). In its transverse section, and the number of lateral tubercles (15 in the Spiti form, 14 in the European specimen referred to), there exists almost complete identity. There is only this noteworthy difference, that in the considerably larger specimen from Chabrang, the ribs are only very indistinctly developed on the siphonal part. Therefore they can only be seen in a side light. However, so much can be distinctly observed that two very flat folds rise from one tubercle crossing the external part in a forward-bent curve.

I do not hesitate in determining this ammonite as *Stephanoceras cf. coronatum*, Brug., and the beds including it must therefore be considered as Kelloway. The overlying beds of 370 feet in thickness, in places very rich in brachiopoda, will have to be included in the uppermost oolite.

Seeing that Kelloway is *in situ* 370 feet below the base of the Spiti shales, the lias must lie considerably lower. Therefore it is quite possible that the beds with *Spiriferina cf. obtusa* actually represent the lias. At any rate a great part of the limestone series in question must be of liassic and jurassic age. On the other hand there is little doubt that the lowest 300 to 400 feet are of upper triassic age, while higher up the rhaetic must be represented. To define the various horizons accurately will be a very difficult task, owing to the scarcity of determinable fossil remains.

Gieumal sandstones and Chikim limestone.

As to the beds following above the Spiti shales, I have only a few points to mention. Wherever well exposed, the Gieumal sandstone alternates at its base with the Spiti shales, a feature already observed

by Messrs. Stoliczka, Griesbach and Diener. South of Gieumal many bivalves mostly of poor preservation occur. Near Chikim and Kibber we observed casts of ammonites belonging to *Perisphinctes* and *Stephanoceras*.

The Chikim limestone of Chikim itself has yielded *Foraminifera*, recorded already by Ferdinand Stoliczka. They belong to the genera

Cristellaria,
Dentalina, and
Haplophragmium.

In the Lingti valley a belemnite was observed in this limestone.

The sequence of beds included between the productus shales and the Spiti shales is given in the following table :—

SPITI SHALES. UPPER JURASSIC.

Grey and black earthy limestones, passing gradually into the Spiti shales. About 2,300 feet.	*Stephanoceras cf. coronatum*, Brug. . About 1,800 to 1,900 feet above base.		Oolite ...
	Spiriferina cf. obtusa, Opp. . . About 800 to 900 feet above base.		Lias. ... Rhaetic.
	? *Spirigera noetlingi*, Bitt. About 300 feet above base. *Megalodon ladakhensis*, Bitt. About 50 feet above base.	Dachstein-kalk in part.	Upper trias.
White and brown quartzites, black shales and hard grey limestones. From 300 to 350 feet.	*Aulacothyris joharensis*, Bitt. Near top. *Lima cumaunica*, Bitt. *Spiriferina griesbachi*, Bitt. Lower Part.		
Brown weathering, sandy and shaly limestones, sandstones and dolomites. 300 feet.	*Spiriferina griesbachi*, Bitt. *Anodontophora griesbachi*, Bitt. *Aulacothyris joharensis*, Bitt.	Sagenites beds, Diener.	

Brown weathering, sandy and shaly limestones, sandstones and dolomites. 300 feet.	*Distichites* nov. sp. 250 feet above base. *Monotis salinaria*, Br. 200 feet above base. *Spirigera dieneri*, Bitt. Base.	Sagenites beds, Diener.	
Coral limestone 100 feet.	*Spiriferina griesbachi*, Bitt. *Rhynchonella bambanagensis*, Bitt.	Limestone "with *Sp. griesbachi*," Dien.	
Brown weathering, sandy and shaly limestones, sandstones and shales, and black, splintery limestones. About 500 feet.	*Paratibetites tornquisti*, Mojs. *Juvavites aff. Ehrlichi*, Hau. Upper Half.	Halorites beds, Diener.	
	? *Hauerites n. f. ind.*, Mojs. *Paratibetites aff. tornquisti*, Mojs. Near base.	Hauerites beds, Diener.	Upper trias.
Dolomitic limestone About 300 feet.			
Splintery dark limestones, grey shaly limestones and calcareous shales. From 600 to 700 feet.	*Tropites cf. subbullatus*, Mojs. *Tropites aff. discobullatus*, Mojs. *Clydonautilus griesbachi*, Mojs., etc. About 800 feet above base.	Daonella beds.	
Grey earthy shales with shaly limestone partings. About 500 feet.	*Spiriferina shalshalensis*, Bitt. *Rhynchonella lankana*, Bitt. About 300 feet above base. *Joannites cymbiformis*, W. *Trachyceras cf. aonoides*, Mojs. Base.		

Hard, dark, splintery limestone, shaly limestones intercalated. About 300 feet.	*Halobia cf. comata*, Bitt. „ *cf. fascigera*, Bitt. Upper part.	Daonella beds.		Upper trias.
	Daonella lommeli, Wiss. Lower part.		Ladinic stage.	Muschelkalk.
Black, shaly limestones, thin-bedded. 160 feet.	*Daonella indica*, Bitt. „ *lommeli*, Wiss. *Gymnites ecki*, Mojs. *Trachyceraladinum*, Mojs. *Proarcestes bicinctur*, Mojs. *Ptychites gerardi*, Blan.			
Grey and black, concretionary limestones, with thin, shaly partings. About 15 feet.	*Ptychites rugifer*, Opp. *Ceratites thuillieri*, Opp.		Upper muschelkalk.	
	Spiriferina stracheyi, Salter, etc.			
	Ceratites subrobustus, Mojs. *Sibirites prahlada*, Dien *Danubites kansa*, Dien.		Lower muschelkalk.	
Nodular limestone . . About 60 feet.	Very poor in fossils . .			
Grey earthy, concretionary limestones and shales. 40 feet.	*Hedenstrœmia mojsisovicsi*, Dien. *Danubites nivalis*, Dien. Near base.		Upper division of lower trias.	Lower trias.
Black limestone and shales. 6 to 7 feet.	*Proptychites ammonoides*, Waag. *Meekoceras nov. sp.* Upper part. *Ophiceras sakuntala*, Dien Near base.		Otoceras beds.	

Productus shales with *Clyclolobus oldhami*, Waag. Permian.

Abstract *of* Report *on the* Geological structure *of the* sites proposed *for the* Bhavani dam, *by* T. H. HOLLAND, A.R.C.S., F.G.S.

The sites suggested for a dam across the Bhavani valley lie from 4 to 8 miles west of Satyamangalam in the Coimbatore district, and just below the junction of the Moyar with the Bhavani river.

The prevalent rocks in this particular part of the valley are biotite-gneisses of a type generally regarded to be the oldest members of the Archæan group of crystalline rocks. With the biotite-gneisses there occur bands of hornblende schist, quartzites, quartz fuchsite schists, quartz iron ore schists, and members of the charnockite series which have been considerably altered.

The gneisses and schists of the Bhavani valley being situated between two great masses of strong, homogeneous charnockites—the Nilgiris and the Bargur hills—have noticeably suffered severely from the crushing effects of earth movements; but as all such movements ceased in South India early in palæozoic times, when these rocks were deeply buried, the cracks and faults in the gneisses have been completely healed, and their present crushed appearance, due to the preservation of the old scars, is more apparent than real; the gneisses, for all practical purposes, are now as firm as they would have been if they had escaped deformation.

The principal points kept in view whilst examining the proposed sites were—

(1) The distance from the surface of the fresh unweathered rock.

(2) The probable rapidity of alteration on exposure of the fresh rock, to the new conditions near the dam foundations.

(3) The direction and character of the younger joint planes, which would permit percolation of water under pressure.

(4) The coincidence of junction planes between adjoining large formations with the areas of high pressure under the dam, and consequent possibility of differential settlement in the foundations.

(1) The first point had been very thoroughly investigated by the officers of the Public Works Department before the time of my

visit, and the detailed report by Mr. Malet shows the depth of subaërial decomposition at numerous points along each of the proposed sites. It was on account of the great thickness of the soft, weathered rock, that the site A.B.,[1] first selected, was afterwards condemned. Besides the great depths to which the weathering agents have penetrated in the region of the A.B. site, the excavations made to the south of the river cut an intrusion of the peculiar decomposed dunite with magnesite, which is now known in so many isolated patches in South India. Their soft, irregular nature and the readiness with which these rocks (the dunites) lend themselves to hydrous decomposition, render them quite unfit for the foundations of a large dam. There is, therefore, in this discovery an additional reason for abandoning the A.B site, and I entirely agree with the general opinion of the Engineering officers as to its unsuitability.

(2) With the exception of the dunite referred to in connection with the abandoned A. B. site, there are no rocks in the valley noticeably liable to rapid alteration on exposure to the weather or water. The second consideration needs, therefore, no further discussion.

(3) The display of the old fracture scars and the strongly marked foliation of the biotite-gneisses have given rise to ill-founded suspicions as to their stability. Microscopic sections across the fracture planes show the rocks to be completely re-cemented by crystalline material, and to be just as firm now as if they had never suffered any crushing in the past. Similar remarks apply to the foliation planes, which, at the G. H. site, strike nearly east and west, or at right angles to the alignment of the dam. It has been suggested that such a disposition of the foliation planes parallel to the river bed, and across the line of the dam, will facilitate the percolation of water under the dam; but it should be remembered that though the disposition of the constituent minerals, especially of the mica scales, in bands, permits an easy clearage of isolated fragments along the foliation planes, these planes are perfectly closed up in the rock mass. The *tendency* to easy clearage, due to the thin films of mica principally, is quite consistent with the absence of actual open fissures in the rock mass. The principal channels for percolation would be along the younger joint planes, which occur as frequently

[1] Three alternative sites known respectively as the A.B., C.D. and G.H. sites were examined, and their positions marked on a geological map accompanying the original report.

across, as along the foliation, and in this particular respect the biotite-gneiss is as sound as most rocks, whilst its composition is unfavourable to any form of solution in water which would tend to widen such joint planes and convert mere cracks into open fissures. I do not consider, therefore, that the direction of the foliation planes can be fairly offered as objection to the G.H. site.

(4) The disposition of the garnetiferous basic rock (garnetiferous amphibolite) forming the small hill along the site C.D., illustrates the fourth point in which the geological features of the site are of importance. It was thought, apparently, that this garnetiferous rock (amphibolite) formed a continuous band along the central portion of the C.D. site; but excavations made at the point where the C.D. line crosses the Bhavani river, reveal the ordinary biotite-gneiss on the left (N.) bank of the river, whilst the amphibolite is found to strike across at a higher point. On following the C.D. line towards C. the amphibolite is again meet with, and then continues as a ridge for over hall a mile in the west-north-west direction, that is, parallel to the direction of the similar ridge on the right (S.) bank of the river, but not exactly in line with it; the two ridges are in fact arranged *en echelon*, and the two bands of amphibolite are thus not actually continuous with one another. Either they are parts of a band dislocated by a fault plane near and parallel to the river, or, which is more likely from what we know of the habits of this peculiar rock, the two bands are separate, lens-shaped intrusions into two fissures, parallel to one another, and coincident with the foliation planes in the gneiss.

Usually the lenticular bodies which this rock habitually forms in South India, are stouter and more convex, more definitely lens-shaped in fact. But in the Bhavani valley they have been flattened out by the same earth-movements which have so intensely foliated the associated gneisses, and this fact I did not fully appreciate until I had examined the rocks microscopically. However, the correct geological interpretation of these phenomena is of less importance for the present than the actual fact that at this point, the most critical point in the C.D. site, there is a double geological change, first from amphibolite to biotite-gneiss and, in a short distance, back again to the amphibolite band. Both the amphibolite and the biotite-gneiss would be sufficiently superior to all that will ever be required of them in this respect, that the possibility of differential settlement due to the weight of the dam need scarcely be discussed; but where the

water pressure will be so great as it will be at this the deepest point in the reservoir, and where, in fact, all the enemies to its stability will act with maximum effect on the dam, I should consider it advisable, when possible, to avoid building across the junction planes of two dissimilar geological formations.

In the case of the Bhavani project the existence of an alternative site at G.H. offers a means for avoiding this form of danger. Along the G.H. line there is also a change in the geological formation, but the change is between two rock groups which differ merely in structure, not in mineral composition; the differences between a gneissose granite and a biotite-gneiss of the old type in South India, though of theoretical interest to the geologist, are of no importance from the engineering standpoint. But in this instance, too, the change of formation occurs at a point in the G.H. line which is at a higher comparative level than the double, and more serious change, which has just been referred to in connection with the C.D. site.

From the geological standpoint, therefore, I would give a vote in favour of G.H., but it is only fair to state that had C.D. been the only site available I should not consider the change from biotite-gneiss to amphibolite sufficiently important to justify a protest against its selection. At the same time, when another good site is available without any apparent drawbacks, I should, as a matter of principle, decide in favour of the latter.

There is one point on which a brief explanation is due to the members of the committee who favoured the selection of the C.D. site. When going over the ground I noticed that the margins of the amphibolite lenses showed signs of alteration by dynamical metamorphism, but did not fully appreciate the fact that such an alteration had extended to the centre of the mass until the specimens collected had been prepared for microscopic examination. I expected consequently that the rock of the ridges would be highly jointed until Mr. Larminie showed, by excavations made on the Pungur hill, south of the river, that the amphibolite was far more massive than I had expected. The point which I raised in committee, namely, that the jointed rock of the ridges would permit free percolation, must therefore be withdrawn. The amphibolites are, I find, slightly decomposed with formation of carbonate of lime, and they contain also considerable quantities of apatite (phosphate of lime), but the proportions of these minerals do not attain anything near a dangerous degree.

Appendix I.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India, from the 1st April 1899 to the 31st March 1900.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Library.
„ „ „ Museum.
BALTIMORE.—Johns Hopkins University.
„ Maryland Geological Survey.
BERLIN.—Deutsche Geologische Gesellschaft.
„ K. Preuss. Akad. der Wissenschaften.
„ „ Geologische Landesanstalt.
„ „ „ und Bergakademie.
BOLOGNA.—R. Accad. dellé Scienze dell' Istituto de Bologna.
BOMBAY.—Bombay branch of the Royal Asiatic Society.
„ „ Natural History Society.
BORDEAUX.—Société Linneenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
„ „ Association for the Advancement of Science.
„ Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australasia.
„ Royal Society of Queensland.
BRISTOL.—Bristol Museum and Reference Library.
BRUSSELS.—Société Royale Belge de Geographie.
BUCHAREST.—Muse.
„ Museului di Geologia si di Palæontologia.
BUDAPEST.—Kön. Ungarische Geologische Gesellschaft.
„ „ „ Anstalt.
CAEN.—Société Linneenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of Bengal.
„ Asiatic Society of Bengal.
„ University of Calcutta.
„ Editor, Indian and Eastern Engineer.
CAMBRIDGE.—Philosophical Society.
„ Woodwardian Museum.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CANADA.—Hamilton Association.

CAPE TOWN-CAPE OF GOOD HOPE.—Geological Commission.
CHICAGO.—Field Columbian Museum.
COPENHAGEN.—Academié Royale des Sciences et des Lettres.
DES MOINES.—Jowa Geological Survey.
DRESDEN.—Naturforschende Gesellschaft.
DUBLIN.—Royal Dublin Society.
„ Royal Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
FRANKFURT-AM-MAIN.—Senckenbergische Naturforschende Gesellschaft.
FREIBURG IN BADEN.—Naturforschende Gesellschaft Isis.
GENEVA.—Sociétè de Physique et d' Hist. Nat. de Geneva.
GLASGOW.—Glasgow University.
GÖTTINGEN.—Königl. Gesells. der Wissenschaften.
HALIFAX.—Nova Scotian Institute of Science.
HALLE.—Academia Cæsarea Leop. Carol. Nat. Curiosorum.
„ Naturforschende Gesellschaft.
HELSINGFORS.—Commission Geologique de la Finlande.
„ Société Finlande de Geographie.
INDIANA.—Department of Geology and Natural Resources.
„ Indiana Academy of Science.
JOHANNESBURG.—Geological Society of South Africa.
KÖNIGSBURG.—König. Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Societe Vandoise des Sciences Naturelles.
LAWRENCE.—Kansas University.
LEIPZIG.—Kön. Säch. Gesells. der Wissenschaften.
„ Verein für Erdkunde.
LIEGE.—Société Geologique de Belgique.
LILLE.— „ „ du Nord.
LISBON.—Travaux Geologiques du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Association for the Advancement of Science.
„ British Museum (Natural History).
„ Geological Society.
„ „ Survey of the United Kingdom.
„ Iron and Steel Institute.
„ Linnean Society.
„ Royal Geographical Society.
„ „ Institution of Great Britain.
„ „ Society.
„ Society of Arts.
„ Zoological Society.
„ Imperial Institute.
MACON.—L'Institut Colonial di Marseille.
MARSEILLE.—Faculte des Sciences de Marseille.
MADRID.—Sociedad Geografica de Madrid.

MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-supply.
„ Royal Society of Victoria.
MEXICO.—Instituto Geologico de Mexico.
MILAN.—Societa Italiana di Scienze Naturali.
MOSCOW.— „ Imp. des Naturalistes.
MUNICH.—Kōnigl. Bayerische Akad. der Wissenschaften.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
„ American Museum of Natural History.
NEUCHATEL —Société des Sciences Naturelles.
OTTAWA.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
PARA.—Museu Paraense de Historia Naturelle Ethnographia.
PARIS.—Department of Mines.
„ Ministere des Travaux Publics.
„ Museum de Histoire Naturelle.
„ Societe de Geographie,
„ „ Geologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PERTH.—Geological Survey, Western Australia.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Societa Toscana de Scienze Naturali.
PRETORIA.—State Mining Department.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Lincei.
„ „ Comitato Geologico d'Italia.
„ Societa Geologica Italiana.
SAIGON.—Economique d'l' Indo-Chine.
SALEM.—American Association for the Advancement of Science.
„ Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SINGAPORE.—Straits Branch of the Royal Asiatic Society.
STOCKHOLM.—Konig. Svenska Vetenskaps Akademiens.
„ Sveriges Geologiska Undersokning.
ST. PETERSBURG.—Academie Imperiale des Sciences.
„ Comite Geologique.
„ Russ. Kais. Min. Gesellschaft.

SYDNEY.—Australian Museum.
„ Geological Survey of New South Wales.
„ Linnean Society „
„ Royal „ „
„ Department of Mines and Agriculture.
„ Australasian Association for the Advancement of Science.
TOKIO.—College of Science, Imperial University.
„ Deutsche Gesellschaft für Natur-und Völkerkunde.
TOPEKA.—University Geological Survey of Kansas.
TORONTO.—Canadian Institute.
TURIN.—Reale Accad. delle Scienze.
UPSALA.—Geological Institution, University of Upsala.
VENICE.—R. Instituto Veneto di Scienze Lete ed Arti.
VIENNA.—K. Akad. der Wissenschaften.
„ K. K. Geographische Gesellschaft.
„ „ Geologische Reichsanstalt.
„ „ Natur. Historisches Hofmuseum.
WASHINGTON.—Smithsonian Institution.
„ United States Department of Agriculture.
„ „ „ Geological Survey.
„ „ „ National Museum.
„ „ „ „ Academy of Sciences.
WELLINGTON.—New Zealand Institute.
YORK.—Yorkshire Philosophical Society.
ZURICH.—Naturforschende Gesellschaft.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL 1899 TO 31ST MARCH 1900.

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- „ VI, „ 4.
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1 : 75000. Fol., 1898.

Appendix II.

The Inspector of Mines in India.

MR. JAMES GRUNDY.

The annual report, which the Inspector of Mines should submit for the Calendar year 1899, has not been sent in up to date, but the Office Records show that during 1899, mines were inspected in Bengal, the Punjab and in Baluchistan. The total number of days on which inspections were actually made, was only 77, whereas 82 days were spent either on office work in camp, or travelling to and from head-quarters.

CALCUTTA:
The 31st March 1900.

C. L GRIESBACH, *Director,*
Geological Survey of India.

G. I. C. P. O.—No. 3 D. G. Survey.—28-6-1900.—600.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1901

TO THE 31ST MARCH

1902.

UNDER THE DIRECTION OF

C. L. GRIESBACH, C.I.E., F.G.S.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA,

CALCUTTA:
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

CONTENTS.

GEOLOGICAL SURVEY OF INDIA.

Director.

C. L. GRIESBACH, C.I.E., F.G.S.

Superintendents.

1. R. D. Oldham, A.R.S.M., F.G.S., returned from furlough on the 17th July 1901.
2. Tom D. LaTouche, B.A., F.G.S., on privilege leave from 11th September to 18th October 1901.
3. C. S. Middlemiss, B.A., F.G.S., returned from furlough on 18th December 1901.

Deputy Superintendents.

1. P. N. Bose, B.Sc. (London), F.G.S., on privilege leave from 30th May to 1st July 1901.
2. T. H. Holland, A.R.C.S., F.G.S., also Curator up to 18th March 1901, and Officiating Superintendent *vice* Messrs. Oldham and Middlemiss from 6th July 1899 to 17th December 1901. On combined privilege leave and furlough from 29th October 1901.

3. P. N. DATTA, B.Sc. (London), F.G.S., also Officiating Superintendent *vice* Mr. Middlemiss from the 7th June 1900 to 16th July 1901. On privilege leave from 14th August to 28th October 1901, and Officiating Superintendent *vice* Mr. Holland from 29th October to 17th December 1901.
4. F. H. Smith, A.R.C.S., returned from furlough on 18th November 1901.

ASSISTANT SUPERINTENDENTS.

1. H. H. HAYDEN, B.A., B.E., Officiating Deputy Superintendent from 6th July 1899 *vice* Mr. T. H. Holland, also Curator from 19th March 1901 *vice* Mr. T. H. Holland.
2. E. VREDENBURG, B.L., B.Sc. (Paris), A.R.C.S., also Officiating Deputy Superintendent *vice* Messrs. Smith and Middlemiss from 9th May 1900 to 17th December 1901.
3. T. L. WALKER, M.A. (Kingston), Ph. D. (Leipzig), also Officiating Deputy Superintendent *vice* Mr. P. N. Datta from 7th June 1900 to 16th July 1901. On extraordinary leave for 2 months with effect from 29th October 1901. Resigned appointment with effect from 28th December 1901.
4. A. KRAFFT von Dellmensingen, Ph. D. (Vienna), also Officiating Palæontologist *vice* Dr. F. Noetling, from 1st May 1901. Died at Calcutta on the 22nd September 1901.

PALÆONTOLOGIST.

FRITZ NOETLING, Ph. D. (Berlin), F.G.S. *On privilege leave combined with furlough from 1st May to 29th October 1901.*

SPECIALISTS.

1. G. A. STONIER, A.R.S.M., F.G.S., also Officiating Inspector of Mines in India *vice* Mr. Grundy from 13th March 1901. Appointed Chief Inspector of Mines in India with effect from 7th January 1902.
2. R. R. Simpson, B.Sc., in Mining (Dunelm), also Officiating Inspector of Mines with effect from the 13th November 1901.

SUB-ASSISTANTS.

1. HIRA LAL.
2. KISHEN SINGH, F.G.S.

ARTIST.

H. B. W. GARRICK.

ASSISTANT CURATOR.

T. R. BLYTH. Appointed Assistant Curator from 13th February 1901.

REGISTRAR.

A. E. MacA. AUDSLEY.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1901

TO THE 31ST MARCH

1902.

PART I.—HEAD-QUARTER NOTES.

Director's tours.

During the year under report, I carried out the following tours:—

PUNJAB AND KASHMIR.

(1) I proceeded to the Punjab and Kashmir, leaving Calcutta on the 7th September and returning on the 17th October, for the purpose of studying the lower trias sections of the Vihi and Scind valleys in greater detail than was done by Mr. Lydekker, who had surveyed Kashmir many years ago. The very important task still remains of correlating the lower trias of Kashmir with that of the Central Himalayas and also the Salt range in the Punjab. It is hoped that these studies will be commenced during the summer months of 1902.

UPPER BURMA.

(2) From the 11th November to 8th December I remained in the northern Shan States of Burma for the purpose of inspecting the progress of work carried on by Messrs. LaTouche and Datta,

who had completed the survey of a very large tract of country. Some of the points on which these two officers differed in their interpretation were carefully discussed, and as these considerations were mainly based upon fossil evidence, Dr. Noetling, the Palæontologist of the Department, was also deputed to Burma to aid in these revisions.

CHOTA NAGPORE.

(3) During March 1902 I visited Mr. F. H. Smith's party which is engaged in the examination of the auriferous localities in Chota Nagpore. As will be seen further on, the results obtained so far are not very encouraging, but nevertheless this inquiry will have to be carried on until at least all the localities which had once upon a time been either prospected or worked for useful minerals have been subjected to a thorough examination.

Changes on the Staff.

During the year under report the Department lost the services of four officers: two geologists on the regular staff, and two mining specialists. Dr. von Krafft died suddenly on the 22nd September 1901, but not without leaving behind him valuable reports and manuscripts which will be published in the Memoirs of the Department. By his death the Department suffers a most serious loss; Dr. von Krafft was not only specially trained for scientific work, but he was an exceptionally keen mountaineer and as such invaluable as an explorer of the highest portions of the Himalayas.

Dr. T. L. Walker resigned his appointment on the 28th December 1901, having been nominated Professor of Mineralogy at the University of Toronto.

Mining Specialists.

Mr. G. A. Stonier was appointed officiating Chief Inspector of Mines and as such acted under my supervision, but on the Inspection of Mines office being established as a separate department under Government, Mr. Stonier was confirmed as Chief Inspector of Mines under date 7th January 1902, and the Geological Survey lost his services as specialist.

Mr. R. R. Simpson was appointed by His Majesty's Secretary of State for India a coal-specialist on the 13th November 1901, but his services were utilised as Inspector of Mines under Mr. Stonier.

It will thus be seen that owing to deaths, resignations and the necessities of the Inspection of Mines Office, the Department was deprived of the services of four officers during the greater part of the

year, to which must be added the absence on furlough during part of the year under review, of Messrs. Oldham, Middlemiss, Holland, Smith and Dr. Noetling. which casaulties have greatly reduced the total output of work which might have been expected from the Department.

1.—Museum and Laboratory.

During the past year the curatorship was held from June till November by Dr. T. L. Walker and for the remainder of the year by Mr. Hayden.

The arranging, cleaning and labelling of the cases has progressed steadily. It has also been found necessary to undertake the complete cleaning and re-labelling of the large and valuable "Klipstein" collection of foreign fossils: for this purpose a special grant has been sanctioned by the Government of India and a staff of native label-writers has been engaged. The work of cleaning the cases and specimens will probably be completed by June 1902, but more than a year will be required for the re-labelling.

Several valuable additions have been made to the collections during the past year, one of the most interesting of which is the Sindhri meteorite; this is a stony meteorite, weighing 7,837 grammes, which fell on 10th June 1901. It may be remarked in this connexion that the Government of India, Department of Revenue and Agriculture, Circular No. $\frac{45\,G.}{82\text{-}13}$, dated 28th April 1885, enjoining the despatch to the Geological Section of the Indian Museum of all meteorites falling in British territory, has become practically a dead-letter, and the attention of local Governments and of district officials might with advantage be drawn to it.

The following donations have been received during the year :—

	Donor.
Seven meteoric irons . . . . Seven stony meteorites	Prof. H. A. Ward, Chicago.
Specimens of muscovite from Inikurti, Nellore district	E. H. Sargent, Esq., Nellore.
Copper and copper slag, obtained in the smelting of Chalcopyrite, from Komai, Darjiling district.	F. Thompson, Esq., Sam Sing, Jalpaiguri.

Over three hundred assays and determinations, detailed lists of which will be found in the quarterly notes, have been made in the Laboratory during the past year.

The curator reports that he is greatly indebted to Mr. T. R. Blyth, Assistant Curator, for the valuable assistance rendered by him in the Museum and Laboratory.

2.—Palæontological work.

During the year the collection of fossils belonging to the department was largely augmented by most valuable additions collected by (1) Messrs. La Touche and Datta in Burma, (2) Mr. Hayden in Spiti, and (3) Mr. Vredenburg in Baluchistan. The naming and cursory examination of the same will take the entire recess season of 1902, but it will take years to fully describe the most important part of these fossil collections, and this will only be possible through the co-operation of palæontologists at home, as the material is of far too vast a nature for one specialist to describe during a life-time.

(a) *Descriptive work in India.*

DR F. NOETLING.
Tertiary fossils of Sind.

Dr. F. Noetling returned from leave on the 29th of October and resumed the description of the Tertiary fauna of Sind, in particular that of the Nari stage. The determination and description of the *Pelecypoda* is almost finished, but it is not intended to publish it as a separate memoir until the *Gastropoda* are completed, which will enable him to form a more accurate opinion on the fauna generally.

The examination of the *Pelecypoda* points to the conclusion that the age of the Nari stage can hardly be older than the Priabona beds of upper Italy, though it is even possible that they are somewhat younger. The Nari stage may therefore represent the top of the eocene series. The examination of the *Pelecypoda* has further proved that there is hardly any faunistic similarity between the Nari and the younger Gaj stage. This is a very important fact inasmuch as it would prove a faunistic break between the eocene-Nari and the miocene-Gaj series.

The description of the lower trias fossils of the Himalayas engaged Dr. von Krafft during the entire recess season of 1901 up to the day of his death. It is as yet impossible to say how far his descriptions of new species are ready for publication. Amongst his papers were found more or less complete descriptions of species belonging to the following genera:—

DR. VON KRAFFT *on the lower trias fossils.*

1. *Meekoceras*, Hyatt.
2. *Ceratites*, de Haan.
3. *Xenodiscus*, Waag.
4. *Hedenstrœmia*, Waag.
5. *Frechiceras*, nov. gen.
6. *Sibirites*, Mojs.
7. *Proptychites*, nov. gen.
8. *Flemingites*, Waag.
9. *Nannites*, Mojs.

These are also partly illustrated by drawings, but the work of revising the text and comparing the type specimens with the same, not less than selecting suitable figures to illustrate those which have not yet been figured, has still to be done. The work when completed will no doubt form a very valuable contribution to triassic palæontology, even should it turn out to consist of fragmentary notes only.

(*b*) *Descriptive work in Europe.*

The work mentioned on page 4 of last year's General Report is still in progress.

Professor R. Zeiller has entirely finished the description of the Gondwana flora, and the work is printed and will appear within the next few weeks.

IN FRANCE.

Dr. F. L. Kitchin has furnished the full description, with plates, of the *Trigoniæ* of the Kutch fauna, which will now be published as part 2 of Volume III, Series IX, of the Palæontologia Indica.

IN ENGLAND.

There is only a small remnant, consisting of the remainder of the *Lamellibranchiata*, which is awaiting description by Dr. Kitchin, which will be done during next year.

The older palæozoic fossils of the Himalayas, the description of which should be contained in Palæontologia Indica, Series XV, Vol. I,

are still in England awaiting naming, but up to date it has not been possible to secure the services of an expert. Palæontologists are few in England, and apparently there are none with sufficient time at their disposal to undertake Indian work.

IN AUSTRIA.

1. Professor V. Uhlig has sent a first small instalment of the description of the Spiti fauna consisting of the genera *Phylloceras*, *Lytoceras*, *Haploceras*, *Hecticoceras*, *Oppelia*, *Aspidoceras* and *Holcostephanus*, which will be illustrated by 18 plates. There are 74 plates lithographed up to date, so it may be expected that the description of the remaining genera will require several years for their completion.

2. Professor Dr. Diener is at present engaged in describing the permian and carboniferous fossils of the Himalayas, which had recently been collected by Mr. Hayden and Dr. von Krafft, and these will probably not be finished before the end of 1902-1903. He has also promised to undertake the description of the new additions to collections of upper trias fossils.

3.—Publications and Library.

The following publications were issued during the past twelve months:—

General Report.

General Report on the work carried on by the Geological Survey of India, from the 1st April 1901 to the 31st March 1902.

Memoirs.

Volume XXX, Part 3. Sivamalai series of the Eleolite-Syenites, by T. H. Holland.

Part 4. Report of the Geological Congress of Paris, by Dr. W. T. Blanford, F.R.S.

Volume XXXI, Part 1. Geology of the Son valley in the Rewah State, etc., by R. D. Oldham, P. N. Datta and E. Vredenburg.

Part 2. A Geological sketch of the Baluchistan Desert and part of eastern Persia, by E. Vredenburg.

Part 3. Petrological notes on some Peridotites, Serpentines, etc., by Lieut.-General C. A. McMahon, F.R.S.

Volume XXXII, Part 1. Recent Artesian experiments in India, by E. Vredenburg.

Part 2. Report on the Rampur Coalfield, by G. F. Reader.

Volume XXXIII, Part 2. On some auriferous localities in India, by H. H. Hayden and Dr. F. H. Hatch.

Volume XXXIV, Part 1. On a peculiar form of altered peridotite in Mysore State, by T. H. Holland.

Palæontologia Indica. New series Vol. I, No. 3. Fauna of the Miocene Beds of Burma, by Dr. F. Noetling.

Series X, Vol. IV. Title page, contents, etc.

Series XV, Vol. III. Title page, contents, etc.

Popular Guide to museum. Meteorites, No. 3, Appendix.

Inspector of mines. Annual Report of the Inspector of mines for the year ending 31st December 1900.

Library. The additions to the library during the year 1901-02 amount to 1,922 volumes of which 1,132 were acquired by presentation and 790 by purchase.

PART II.—FIELD PARTIES.

Distribution of officers. During the year ending the 31st March the officers of the Department were posted as follows:—

SUPERINTENDENTS.

Mr. R. D. Oldham . .	Returned from furlough on the 17th July 1901; was posted to the survey of the Simla hills and the Sulaiman hills west of Dera Ghazi Khan. Left Calcutta on the 29th August 1901 and returned to headquarters on the 18th March 1902.
Mr. T. H. D La Touche .	Returned to headquarters from the northern Shan States on the 29th April 1901; engaged in drawing up his report. Was again posted to the northern Shan States from the 3rd November to date.
Mr. C. S. Middlemiss .	Returned from furlough on the 18th December 1901 and was posted to the Vizagapatam hill tract from the 8th January to date.

DEPUTY SUPERINTENDENTS.

Mr. P. N. Bose . .	During April was engaged in surveying parts of the Jhaintia hills of Assam; returned to headquarters on the 11th May 1901, where he was engaged in drawing up a report on the previous season's work. Was posted to the same area for the cold weather period and left Calcutta for the field on the 2nd December 1901.
Mr. T. H. Holland . .	During April 1901 was engaged in examining the neighbourhood of Dharmsala hill station and afterwards was posted to the survey of the Kangra district. Returned to Calcutta on the 22nd September and left on furlough on the 29th October 1901.
Mr. P. N. Datta . .	During April and part of May was engaged on the survey of the northern Shan Sates; returned to headquarters for recess work on the 13th May 1901 and during the cold weather months was again posted to the same area; left for it on the 5th November 1901.
Mr. F. H. Smith . .	Returned from furlough 18th November 1901; was posted to the Chota Nagpore mineral survey and left for his post on the 5th December.

ASSISTANT SUPERINTENDENTS.

Mr. H. H Hayden . .	During the rainy season of 1901 was deputed to the Spiti Himalayas to complete his previous surveys of that area. Left on the 7th June 1901, returning from there on 29th October, when he took over the duties of curator of the Museum. On the 4th March he was deputed to Assam to report on the condition of the hill section of the Assam-Bengal railway and the coal-seams which occur in the neighbourhood.

Mr. E. Vredenburg . .	Had been posted to Baluchistan during 1900-1901 and remained there till the 1st October 1901 when he returned to headquarters for the purpose of describing his collections. He returned to the survey of Baluchistan in February 1902.
Dr. T. L. Walker . .	Curator during the recess season of 1901; resigned his appointment in October 1901.
Dr. A. von Krafft . .	At headquarters during the recess season of 1901; died on the 22nd September 1901.

PALÆONTOLOGIST.

Dr. F Noetling . .	On furlough during the recess season till 29th October 1901; accompanied the Director on a tour to Burma during November and December. In March 1901 was deputed to examine the Sambhar Lake in Rajputana.

SPECIALIST.

Mr. G A. Stonier . .	During April 1901 was performing miscellaneous duties in connection with Mines inspection, and also was on deputation to Bikanir to select boring sites. Later engaged on the Jherria coal survey. Services transferred to the Department of Revenue and Agriculture as Chief Inspector of Mines in India, 7th January 1902.

SUB-ASSISTANTS.

Hira Lal and Kishen Singh.	Were during 1901-1902 attached to parties of Messrs. Stonier, Datta and Smith.

ASSISTANT CURATOR.

Mr. T. R. Blyth. . .	Was on duty at the Museum during the entire year under report.

A.—ECONOMIC ENQUIRIES.

I.—Gold.

CHOTA NAGPUR.
Mr. F. H. Smith.
Sub-Assistant Hira Lal.

During the year under report only one party could be spared for systematic gold prospecting and that could only be done on a limited scale in Chota Nagpur. Mr. Smith, assisted by Sub-Assistant Hira Lal, examined parts of the Anandpur, Porahat and Manharpur districts of Singbhum, lying to the north of Sonua and Goilkera, and to the north and south of Manharpur stations of the Bengal-Nagpur Railway.

Director.

I myself visited the party during March and was much pleased at the progress made in the prospecting operations, regarding which Mr. Smith has sent in a preliminary report from which the following notes may be quoted:—

Geology.

"The geology of the area is very simple on the whole. The rocks consist of the schists and slates of the transition system, with a very constant east and west strike, and dip varying from vertical to 50° N. At the same time there is a good deal of local crushing of the beds, with frequent evidence of faulting on a limited scale. In the hilly country the rocks are traversed by well-defined sets of cleavage and joint planes; but the pressure which caused them has often disappeared, especially near the hill-tops, and the rocks shew a tendency to fall open, giving rise to extensive vertical fissures, which penetrate far into the hill-side. These fissures are a source of considerable confusion. The old workings are frequently found passing into them, and as the fissures are generally filled loosely with fragments fallen in from the sides, it is difficult to tell where the fissure begins and the working ends. It is quite possible that the ancients followed these clefts originally, taking them for 'older workings' and hoping to find treasure in them.

The country rocks shew much weathering, and they are hydrated to a considerable depth. The most common type is a soft greenish clay-slate, locally steatitic or sandy. The harder rocks consist of chloritic, micaceous, hornblendic and haematitic schists, with their bands of compact felsite. They shew, under the microscope, signs of great crushing and metamorphism, having a general epidioritic

appearance, with a few strings and trails of mylonitic quartz fragments and minute crystals of chlorite or mica, and some secondary calcite. Occasional beds of compact dolomite occur, and also bands of segregated haematite and quartz-haematite breccia, in the slates.

Trap dykes are of somewhat rare occurrence. Quartzite beds are also very exceptional. A broad band of quartz-haematite schist occurs in the Ankwabanga hill, and is slightly auriferous; but the only distinct bed of quartzite met with is that mentioned by Dr. Hatch at Parhardiah. This is twenty or thirty feet in thickness and traverses the country for a long distance, being seen again in the Koel river at Bera, eight miles to the north-east. There are probably one or two smaller beds associated with this main band at Parhardiah, and the rock is auriferous, though the gold appears to be very thinly disseminated through it.

Some of the leaders mentioned below, and possibly one or two of the reefs, may also be due to the metamorphism of original quartzite beds in the slates, but the great majority are probably true reefs—fissures gradually filled up with secondary quartz deposited with other minerals by percolating water.

Quartz reefs.

Quartz reefs occur abundantly throughout the transition rocks, and the hilly jungle tracts are covered with quartz pebbles and boulders derived from their outcrops.

The reefs may be conveniently divided into three classes by their visible characteristics.

Class 1.—Conspicuous reefs of compact, pure white, 'hungry-looking' quartz, which stand out boldly from the surface, and have a considerable influence in the shaping of the country, often occurring along the crests of hills. These seldom contain more than minute traces of gold, and may be neglected by the gold-seeker.

Class 2.—Reefs of a foot or more in thickness, of ferruginous quartz, generally blue or grey in colour. The latter characteristic is probably quite accidental, but the presence of iron scattered through the quartz constitutes the chief difference from class 1.

The presence of iron is a sure sign of the likelihood of gold, and most of these reefs are auriferous.

The iron also affects the physical character of the reef. The films and threads of iron ore are quick to hydrate, and the soft mineral resulting is washed out of the crevices, leaving the reef honeycombed and quite unable to withstand weathering in the way

the compact 'hungry,' quartz-reef does. As a matter of fact the reefs of class 2 seldom reach the surface intact, being disintegrated below; and in many cases this goes on to such an extent that for some feet below the surface, even of the country rock, the reef may be traced down as a band of rubble consisting of fragments of quartz set in red mud, washed in from above and augmented by the hydrated iron. When this occurs at the bottom of an old working, it is impossible to tell exactly where man's work left off and nature's began.

.*Class 3—'Leaders.'* This is a convenient term to denote thin strings and veins of quartz generally from half to three or four inches in thickness. The transition rocks of this area are seamed by such leaders everywhere and in all directions. The great majority of them resemble the reefs of class 2, being of blue, ferruginous quartz usually auriferous and often fairly rich in gold.

Reefs are found cutting the rocks in all directions, but as they were originally deposited in fissures along a line of weakness, it is natural to find that they shew a decided preference to follow a joint plane, and still more often the plane of bedding . . . ."

Mr. Smith's report contains also some interesting notes on the traces of gold contained in the alluvial deposits and in the débris at the foot of hills, which are frequently worked by the native race of gold-washers, but it is quite evident that these gold sources have no practical importance for the scientific miner, beyond guiding him in some instances in his prospecting operations.

Old workings.

More important are the so-called old workings, which abound in Chota Nagpore and which are well known to the natives,—Kols or Mundas—who do not seem to possess any very well defined traditions about the origin of these old "mines." Mr. Smith has carefully examined a large number of these old workings situated in the districts named above. To do so they had to be completely "un-bottomed" in every single instance, as no indications are shown at the surface of the purpose for which the workings had been undertaken. I have myself seen the ancient workings in Rhodesia, South Africa, and can state with certainty that the latter differ in most instances much from these Chota Nagpore workings, although geologically there is a close resemblance in the geology and even the character of the reefs found in both areas. The Chota Nagpore workings differ also, as far as examined, from the numerous old workings in Mysore, which latter seem to show the possession by the ancient miners of greater skill and mining system.

Every indication seems to point out that the Chota Nagpore workings, as far as examined, are nothing more than old prospecting shafts and trenches, and in most cases appear to have been planned by unskilled men, and must have been abandoned by them without having led to the discovery of paying reefs, in the same manner as was done by so-called experts during the late gold "boom" in 1889 and 1890. Whether any of the many hundreds of these old workings will actually be found to be the remains of ancient gold mines, only a long continued and careful search will reveal.

All that can now be said after Mr. Smith's carefully conducted inquiry is that practically all the quartz reefs, together with the network of leaders which traverse the country, contain a certain amount of gold, the richest amongst them from three to four dwt., but then only in patches. If may be said that the average yield is not more than a dwt per ton, which under the circumstances could never pay for regular mining operations.

Galena and gold.

Only one of the smaller reefs, hardly to be called such, but rather a small irregular leader, gave encouraging results on assay, and in that locality an irregular vein of argentiferous galena contains also an appreciable amount of gold, but the vein nips out and has not been further traced. To test this more extensively, a closer study, *i.e.*, some development has to be done before a definite opinion can be pronounced. The assay of the galena alone, which consists of an irregular string of nests in the quartz, has yielded:—

79·3 per cent. of lead.

34 oz. 2 dwt. 17 grains of silver to the ton of lead, and

11 oz. 2 dwt. 3 grains of gold to the ton of lead.

This result seems to be exceedingly encouraging, but as only a small outcrop has been observed, it will require actual development to prove more than the existence of a patchy vein of galena.

2.—Copper.

Darjiling District.

Mr. Hayden.

Copper ores were known to exist near the south eastern boundary of the Darjiling district, and as they had attracted some attention, it was considered expedient to despatch an officer to the spot for the purpose of obtaining a report on the same. Mr. Hayden was therefore deputed to examine this copper ore. The exact locality is situated

B

about four miles north of Sam Sing Tea Estate in the Jalpaiguri district, and it had not been reported on previously.

The country rock consists of soft grey and green slate belonging to the Daling series, and is greatly crushed and contorted with a general strike of north-east to south-west and usually a high dip to north-west. Small bodies of copper ore occur at various places in the slates and in quartzite bands associated with them and usually amount to little more than strings of aggregations of copper pyrites extending for only a few inches in any direction, excepting at one place near the left side of the Mo Chu (Murti river), where the ore is in form of fairly large masses of chalcopyrite with some quartz in bands parallel to the bedding planes of the rock.

The assay value of the ores varies a good deal and no reliable opinion could be given of the value of the locality, as it is scarcely at all developed, but it seems to be encouraging enough to have it developed with the view of ascertaining whether it could not be worked to advantage. A considerable sum of money will be required to develop it extensively enough to ascertain the extent and richness of the ore body, which seems irregular in character.

3.—Coal.

BIKANIR.

Government having sanctioned my proposal to prove the coal-seams of Palana in the Bikanir State by borings, a contract was entered into with a private firm to undertake one diamond drill to a depth of 1,000 feet in order to ascertain whether there are other coal horizons besides the one already known. Mr. Stonier, the specialist of the department, was deputed to Palana to select the site which in all probability would offer the best chances for such a boring, and a tank capable of holding 10,000 gallons of water was also prepared, but it is very regrettable that after a delay extending to about eight months the contractors have failed to carry out the undertaking, the failure being due to their selection of unsuitable machinery for this special locality. As no other private contractors are available in India, the task of proving the coal bearing formation of Bikanir has had to be postponed until Government possesses its own boring plant.

JHERRIA.

Mr. Stonier was deputed in December 1900 to join Mr. Weightman (the Engineer of the Jherria Connection-Survey) at Katras. The objects of the Railway Survey were two-fold—

(1) To determine the best route for a connection between the alignments already selected for the Gya-Katrasgarh (East Indian Railway) and the Midnapur-Boojoodih (Bengal-Nagpur Railway) Railways, to serve as a main line of communication between Mogulserai and Khargpur.

(2) In connection with 1, to consider how branches and sidings can best be laid off this main line, so as to enable the Jherria coal-field to be opened up in such a way that both the East Indian and the Bengal-Nagpur Railways may have equal or reciprocal facilities for dealing with the traffic and may share equally in its expansion, at the same time keeping in view the future development of the coal-field, and the desirability of affording to all colliery proprietors the option of sending their coal by whichever route they may prefer.

After the survey had been in progress for a couple of months and a rough scheme had been decided upon, it became evident that a mining and geological expert's advice was necessary before the alignment of the colliery line could be fixed. It was expected that a month spent on the field would amply suffice for the collection of geological and mining information required for the purposes of the railway survey. It soon became evident, however, (1) that mining operations were confined to a small area, (2) that very little was known about the remainder of the field. At first the chief object was the mapping of the upper seams, but as the work progressed it became necessary to examine the lower seams, and finally the survey of a small area was extended until it embraced the whole field. Jherria was geologically surveyed by Mr. T. H. Hughes in 1865 (*vide* Mem. Geol. Surv. Ind., Vol. V, Part 3), and in 1891 Mr. T. H. Ward (Assistant Manager, E. I. Ry. Collieries) numbered and traced out the seams (Rec. Geol. Surv. Ind., Vol. XXV, Part 2, 1891).

The coal measures occur as an outlier of Gondwana beds surrounded by metamorphic rocks, the boundary in most cases (according to Messrs Ward and Stonier) being a well marked fault. The area is roughly lozenge-shaped with pointed ends, and has a major axis, W. N. W. 27 miles long and minor axis 9½ miles long.

The rocks in descending order are:—

(1) Raniganj system.
(2) Ironstone shales.
(3) Barakar system—
    (*a*) Damuda series.
    (*b*) Talchir series.

(1) The Raniganj beds occupy an area in the south-western portion of the field, and have recently been proved to contain two workable seams of coal, near the base of the system. The seams are not worked on account of the want of the railway communication. It is specially interesting to note this new development in Jherria. Notwithstanding the fact that in the adjoining (Raniganj) coalfield, the Raniganj measures contain the chief seams, an impression had been formed that in Jherria these upper measures did not contain workable coal and the system had been neglected by speculators who confined their attention to the seams in the vicinity of the railway, which was constructed shortly after Mr. Ward's survey.

(2) The Ironstone shales are conformable to the overlying and underlying systems, but the upper and lower boundaries are not well defined as in the case of the Raniganj field. An east and west fault limits the outcrop in the western area, but it spreads out easterly and occupies a fan-shaped area in the south-western portion of the field. The system does not contain but it overlies thick coal seams.

(3) The Barakar system is divisible into two series of which the Talchirs are unimportant from a mining standpoint. The upper series has at least 18 seams (No. 18 was discovered during the progress of Mr. Stonier's survey) which vary from 5 to 30 feet in thickness and have been numbered in ascending order. At both ends of the field the dip is high, but over a large area the seams are well situated for easy and cheap working, though in a number of places they are dislocated by strike faults and penetrated by dykes. The strike faults are numerous and their baneful influence on the value of properties is only beginning to be realized. The dykes are of two kinds, (*a*) mica-peridotite, (*b*) dolerite. The latter are generally unimportant, but the former have been particularly destructive, for they not only cut through the seams, but in many places pass in loccolitic form along the coal rendering it absolutely valueless for the present market. A number of the workable seams are being actively mined, but operations are chiefly confined at present to the winning of coal near the outcrop in the area which lies to the east and south-east of the Khoda river (see Ward's map). The workings are chiefly on seams Nos. 10 to 17 and occupy a narrow strip in the form of an arc of a circle, chiefly to the south of the existing East Indian Railway branch line. The deepest shaft is 320 feet in depth.

The seams below 10 are worked in some parts of the field, but they are not as important as the seams above 10.

At the extreme south-eastern area seams Nos. 13 and 17 are being mined. The former dips at an angle of 28° and the latter at 48°.

In the area west of the Khoda river there is little known about the seams: several of the mouzahs are being prospected by tunnels and deep bores. The general opinion held has been that this end of the field is of little value, but the opinion is based on a small amount of information and at present is not justified. The quality of coal very recently found compares favourably with the average of Jherria coal.

The main line and two colliery lines were pegged out by the Railway Survey party, one running near the outcrop of No. 17 and the other above the outcrop of No. 16 seam. At the conclusion of the field work the East Indian Railway suggested a main line running through the coal-field. A report was written by Mr. Stonier and forms Appendix C. to Mr. Weightman's report, which was furnished to the Government of India. The whole question was considered by a Conference at Simla in July 1901 at which Mr. Stonier was present and gave geological evidence. The report of the Committee which sat at the conclusion of the Conference has been published by the Government of India who adopted most of Mr. Weightman's suggestions

UPPER BURMA, LASHIO.
Mr. La Touche.

The extension of the Burma State Railway from Mandalay to Lashio rendered it desirable to develop the coal-fields of Lashio, concerning which Dr. F. Noetling had furnished a report some years ago. Mr. La Touche being already engaged on survey work in the northern Shan States, he was deputed to undertake the preliminary inquiries and he is now engaged on that work. Concerning the coal seams he reports as follows:—

"The Lashio coal-field is situated in the valley of the Namyao river about five miles to the north of Lashio in Lat. 23° 0″, Long. 97° 50′. The tertiary beds, in which the coal occurs, extend over an area of at least ten miles in length from east to west and two to three miles in breadth. They consist of soft sandstones and sandy clays, without any bands of hard rock, in fact, the hardest rock in the whole series, as seen in the outcrops, is the coal itself. The coal is confined to the lowest beds of the series, and the only outcrops found are situated along the western and southern edge of the basin. To the north and east the coal-bearing beds are overlaid by higher beds of the series, and do not appear anywhere at the surface. It is

impossible to say, without boring, how far the coal extends in that direction, and I have therefore marked sites for borings and arranged with the Engineer-in-Chief of the Mandalay-Kunlon Railway to have them put down as soon as the necessary tools can be procured. The coal as seen in the outcrops, all of which I have had excavated in order that the thickness might be measured, is very variable in thickness, and it is not at all certain that it forms a continuous seam. The thickness varies from 30 feet in the most westerly outcrop, to four feet six inches. No estimate of the total amount of coal available is therefore possible until the continuity of the seams and their extension northwards is proved by borings. Samples of the coal have been taken and will be submitted to analysis. The coal is always found below the natural water level of the country, and is therefore saturated with moisture, and although it can be obtained in large masses it has a tendency to split into small fragments on drying. The roof and floor of the coal is invariably bad, consisting of soft sand or sandy clay, and unless a considerable portion of the coal itself is left as a roof to the workings, much timbering will be necessary. A very considerable water discharge will also have to be contended with."

ASSAM. *Mr. Hayden.*

Mr. Hayden was deputed to Assam to examine the coal seams which occur in the Nambor forest on the eastern flank of the Mikir hills, situated near the Assam-Bengal Railway line. The coal occurs chiefly in two localities, about eight miles west of Borpathar, and in each case the outcrop is seen only in the river bed. The seams lie almost horizontally, striking north-north-east—south-south-west; the coal appears to be dirty and of very inferior quality. The samples are being assayed in the laboratory of the department.

ASSAM. SHILLONG PLATEAU. *Mr. P. N. Bose.*

Coal is occasionally developed in the marginal sandstones of the cretaceous system in the Jaintia hills well within the Shillong plateau. Mr. Bose found two noteworthy occurrences of such coal, one at Wapung (seven miles east of Jowai), and the other at Lenkensmit (Dongchala on map), six miles south of Wapung. It is an excellent caking coal. The seams nowhere exceed five feet or so, and they are, like the nummulitic coal of the area, very variable in thickness. From the exposures observed at both the places, there is a probability of a workable extent of the coal. It will probably, however, have to remain untouched for a long time, as the cost of its transport to the plains of Sylhet and Cachar would be quite prohibitive.

In the area under description workable coal of nummulitic age occurs at Umlotodo (Lakadong) and at Narpo The Lakadong coal (which occurs in a band of sandstones intervening between two bands of nummulitic limestone) has long been well known and was reported upon by Dr. T Oldham in one of the earliest memoirs of the Survey (" Memoirs," Vol. I). It was worked to some extent about 40 years ago, chiefly by adits driven from the steep faces of deep glens where the coal is exposed, and to a small extent by shallow pits. The old workings have been closed since the earthquake of 1897

Nummulitic coal in the JAINTIA HILLS.

4.—Miscellaneous Minerals.

During his geological surveys in the Jaintia hills Mr. Bose discovered two unpromising oil springs The locality is about eight miles east of Mulagul (Lat 25° 3′, Long 92° 29′) close to the eastern feeder of the Dona river. The oil oozes out slowly from greenish grey fine-grained upper tertiary sandstone, similar to the springs in the Khasimara valley, which were reported on last year.

Petroleum. Mr Bose.

One of the first tasks which Mr. Holland undertook during the progress of the Kangra survey consisted in an examination of the slate quarries of Kanyára on which he has furnished a report, now about to appear in Memoirs, Vol. XXXIV, Part 3.

Slate. Mr. Holland.

The Sambhar lake in Rajputana, one of the most important sources of the Indian salt supply, has been observed to furnish diminished quantities of this mineral during the last year, and Dr. Noetling was therefore deputed to specially report on the locality. That officer's selection was in part due to the fact that he has already obtained experience in matters connected with salt owing to his having made a close study of the bitter lakes of Palestine, on which he has published a report.

Salt. Dr. Noetling.

After a careful examination of the geological features, Dr. Noetling found that the lake is an entirely closed basin surrounded on all sides by the Aravali series. This basin of unknown depth is filled up by horizontally bedded, alluvial strata consisting mostly of fine micaceous silt, containing a few beds of hard calcareous strata, locally called

kankar. In several instances it was observed that the alluvial strata rest directly on the Aravali series, and Dr. Noetling concludes therefore that no other beds of either mesozoic or tertiary age exist inside this basin, but that the bottom of the lake is formed by the Aravali series unconformably overlaid by the alluvial silt.

The silt is percolated by a strong brine which rises up to a certain, for the present unknown, level in the centre of the lake and from there radiates towards the shore. The observed fact that in all the wells along the periphery of the lake the brine radiates from the centre is a distinct proof that it must rise from wells in the lake itself, and Dr. Noetling opines that it probably rises under considerable hydrostatic pressure along a fault in the Aravali series which is superficially hidden by the silt. This brine must be considered as the original source of the salt.

When there is a good rainfall, the shallow depression on the surface of the alluvial silt is filled up by a sheet of sweet water of shallow depth; this water takes up the easily soluble sodium chloride from the underlying silt, which it leaches, so to speak, of its saline contents. When the water resting on the silt is agitated by the wind, the more concentrated parts at the bottom are replaced by water less saturated with salt and thus gradually a very pure brine, which chiefly contains sodium chloride, is formed on the top of the silt. By evaporation this brine is more and more concentrated and eventually used for the manufacture of Kyar salt. As the manufacture of Kyar salt is solely dependent on the secondary brine, it is obvious that in years of scanty rainfall, when the lake is not sufficiently filled, the production must fall off, as there is not enough water for the production of the secondary brine. It is further obvious that when there is again a succession of good monsoons, when the lake will be filled to the required depth, the production of salt will rise to its former height.

So far no apprehension should be felt as to probable exhaustion of the lake unless it could be proved that the supply of the primary brine rising within the lake is failing. There are absolutely no observations with regard to this; it is not known whether, for instance, the level of the primary brine has been influenced by the years of scanty rainfall. Dr. Noetling thinks it has not, or at least not materially, because the pits (khals) from which the primary brine is baled out for the manufacture of pan salt are all situated almost along the shores of the lake. If the level of the brine had fallen to some extent, the edge of the brine would have receded towards the

centre, and instead of remaining as they are close to the shore, the pits would have had to be dug further away from it, towards the interior of the lake.

In years of insufficient rainfall, when there is not enough water to fill the Kyars, the production of salt would, therefore, chiefly be dependent on its extraction from the primary brine, and unless it could be proved that the supply of this primary brine is failing, there is no reason to assume that the Sambhar lake has to be abandoned as a source of salt.

5.—Landslips.

ASSAM-BENGAL RAILWAY.
Mr. Hayden.

Early in March Mr. Hayden was deputed to Cachar to report on the geological features of the Hill Section of the Assam-Bengal Railway. He found the local rocks to consist of blue and carbonaceous shales of upper tertiary age, containing some *gypsum* and other soluble sulphates with considerable quantities of *kaolinite.* His analyses of the shale and its component minerals are not yet completed, but he reports that the results so far obtained point to the fact that the movements which have taken place in the cuttings and tunnels are due in part to the presence of the above minerals. The cuttings, however, frequently pass through old landslip material, the removal of a part of which has resulted in a renewal of movement throughout the mass, and until equilibrium has been restored, this movement must continue. He recommends that certain precautions be taken to prevent, as far as possible, serious slips, chief among these being extensive and appropriate drainage. When the analyses of the specimens collected have been completed, a full report will be submitted.

B.—GEOLOGICAL SURVEYS.

1.—Madras Presidency.

VIZAGAPATAM HILL TRACTS.
Mr. Middlemiss.

Mr. Middlemiss returned late in December from furlough and was posted to the Vizagapatam hill tract; he has sent in a short summary and reports as follows:—

"I arrived in camp on the 9th January, so that the present account is the result of only about 2½ months' work, of

which the earlier weeks were spent in familiarising myself with the rock groups treated of by my predecessors Dr. Walker and Mr. Smith. The work done is a continuation of theirs in every respect, and introduces little of any novelty.

I entered these so-called Agency Tracts *vîa* the Minamalur ghât in the Madgole zemindari, and have endeavoured to traverse and partially map in detail the country above the ghâts lying between a line drawn north-west across the hills from the Minamalur ghât and the parts surveyed by Walker. This was chiefly in the Jeypore State, and includes the north eastern part of Atlas sheet 93 (S.E.) and the parts above the ghâts in Atlas sheet 108. The whole area is a portion of the 3,000-feet plateau which here and there bears peaks rising to 4,000 and even 5,000 feet. It is generally forest-covered and sparsely dotted with villages along the flat rice-growing alluvial valleys.

Transitions.

The great series of transition metamorphic rocks, concisely described under the heading of 'Crystalline Schists' by Smith (General Report, G. S. I., 1899-1900, pages 154-157), and as the 'Khondalite Schists' by Walker (Memoir on the Geology of the Kalahandi State, Central Provinces, Mem. Vol. XXXIII, Pt. 3, in the press), are continued southwards, as was to be expected, into the area mapped by me this year. But in this area they present the fuller facies as described by Smith, including considerable beds of ferruginous schists, containing much haematite and limonite and bands of garnet magnetite rock, besides crystalline limestone, etc., and the typical quartz-garnet-sillimanite rock which is everywhere extremely well developed. Although Walker has not mentioned these highly ferruginous varieties of the transition schists, it seems probable that they are not entirely absent in the area mapped by him, as I have traced them up to and even into that area. They are well seen round about Dasmatpur for instance [Atlas sheet 108 (N.)] and are locally used for making iron.

The conjunction of iron-bearing beds with crystalline marble (sometimes, as mentioned by Smith and Walker, containing scapolite and diopside) and with quartz-garnet-sillimanite rock (typical Khondalite of Walker) reminds me of the somewhat similar association of rock types at Madukarai near Coimbatore, at Uttukuli and Viziamangalam, at Satyamangalam, and at other scattered localities in the Coimbatore district.

The great Gneissic series which underlies the transitions includes, as far as I have seen, most if not all the rocks variously grouped as 'garnetiferous biotite-granite and granulite,' and 'hypersthene-granulite' by Smith in Ganjam, and as 'granitoid gneiss' and 'charnockite' by Walker in the neighbouring area of Kalahandi State. It is too early yet to state any positive conclusions, but it seems extremely likely that the charnockite series, though keeping a marked individuality over great areas, docs elsewhere show strange varieties and modifications with apparent passages into more acid biotite-bearing gneisses, as both Smith and Walker have testified (General Report, G. S. I., 1899-1900, pages 158 and 170), and as I have elsewhere described in the Salem district.

Gneissic Series.

Lateritic plateaux at about 4,000 feet are commonly met with from Nelam hill near Wondragedda up to the hills round Girliguma. In all cases which I have examined my observations confirm those of Smith in Ganjam that they are confined to areas of the transition schists, the laterite being directly derived from them by decomposition and concentration of the iron. This seems such a natural and normal result, when the highly ferruginous nature of part of the transitions is taken into consideration, that, in contemplating these striking horizontal plateaux running far round the horizon as they frequently do, the puzzle is not to account for the laterite, but to account for that which it has preserved under its iron-bound cap, namely, the truncation of those hills to about the 4,000-feet level. For, as far as my observations go here, the lateritic plateaux are not horizontal deposits fringing and burying what were once pointed peaks or irregular hills, but a genuine layer disposed above previously truncated hills."

Laterite.

2.—Burma.

The geological surveys undertaken during the season 1900-1901 and reported on in last year's General Report left so many points in Burman geology unexplained, and others on which the several observers differed considerably in their respective views, that it appeared necessary to revise some portions of this survey. A systematic geological survey, as conducted in other parts of the Indian Empire, is quite impossible in Burma owing

NORTHERN SHAN STATES.

Mr. T. D. LaTouche.
Mr. P. N. Datta.
The Director.
Dr. F. Noetling.

to the immense development of dense undergrowth in the vast forests which cover the greater portion of the country, and to this difficulty must be added the great thickness of superficial deposits, mostly of a lateritic nature, which cover all formations alike, and obscures in most places the geological structure entirely.

Accompanied by Dr. Noetling I visited certain parts of the northern Shan States during last cold weather to inspect sections regarding which there were some doubts as to the age of their component beds. The chief sections were those of Kyauk-Kyan, Bawgyo (Kyinsi), Napeng and Gokteik. After this inspection, Mr. LaTouche had to take up the examination of the Lashio coal-field, but before doing so, he devoted some time to further researches near Wetwin and Padaukpin with the result of obtaining from these localities a fine collection of middle devonian fossils.

Wetwin *devonian.*

Mr. LaTouche also succeeded in clearing up some doubts with regard to the presence or otherwise of a boundary fault at Kyauk-Kyan, between beds which had last year been looked upon as mesozoic, and the devonian limestone. These supposed mesozoic shales are undoubtedly devonian as their fossil contents (amongst which is a *Conocardium*) clearly show. The fault, however, does exist, having been proved by Mr. LaTouche by excavating the contact zone. It appears, probably, that the shales are intercalated between the limestone beds, which as may be seen at the Gokteik gorge form a wavy plateau, much shattered by local faults, and in a lesser degree, by extensive jointing.

Kyauk-Kyan *fault.*

The joint visits of myself, with the Palæontologist, Messrs. LaTouche and Datta have satisfactorily established that the Napeng beds, which had been looked upon by Mr. Datta as mesozoic, together with the Kyinsi beds are approximately both of the same horizon, containing absolutely an identical fauna, amongst which a *Conocardium* is always met with, and they are also identical with the Kyauk-Kyan beds, the whole, therefore, forming part of a vast complex of devonian beds which seem to form the greater portion of the Shan plateau in those parts. Whether the so-called Gokteik beds belong to the same horizon may with considerable certainty be inferred, but the fossils are too poorly preserved and moreover are, so far as has been established, not very characteristic. It is pretty certain, however, that so far nothing has been seen of beds which fill in the gap between the devonian and the mesozoic systems. The trias which was inferred last

year (see General Report, 1900-1901, page 19) from some fossils which had been wrongly determined, does not exist. These supposed beds contain devonian fossils and that has been established now beyond a doubt. Certain red shales (with limestones and sandstones) formerly doubtfully supposed to be jurassic, which are considerably developed west of Thebaw (near Namhsim and neighbourhood) have now been demonstrated to be mesozoic, probably either upper jurassic or lower cretaceous. Mr. LaTouche has found numerous well-preserved *brachiopods* in limestone beds of this formation near SeEng in the Namyao valley, and recently Mr. Datta has discovered *Trigonia* in what appear to be the same beds near Hson-oi.

Roughly speaking, therefore, the centre of the Shan plateau consists of palæozoic strata; the bent and much shattered western margin of this plateau being chiefly made up of silurian strata followed eastwards by a devonian sequence, abundantly proved by fossils, and this complex of beds is overlaid in some manner not quite clearly established, by mesozoic (jurassic or lower cretaceous) beds near Bawgyo, west of Thebaw. Whether the lower mesozoic beds with the trias are developed in that region has not been demonstrated yet, but it seems doubtful whether such do exist.

3.—Assam.

JAINTIA HILLS.
Mr. P. N. Bose.

A considerable amount of surveys were added to those completed by Mr. Bose during the last year; the following notes were taken from his preliminary report.

The area surveyed during last season is chiefly comprised between the Mangat and the Lubah rivers. The physical aspect of the eastern portion of the country presents a striking contrast to that of the western. Between the Mangat and the Mantedu (called Harry below Barghat) the undulating, gently-sloping Shillong-Jowai plateau drops suddenly from an elevation of about 1,400 feet to the Sylhet plains, the line of steep declivity corresponding roughly with that of the sharp faulted flexure which the rocks constituting the plateau have suffered at its edge. But east of the Mantedu-Harry river, the plateau to a great extent loses its distinctive character running into bold, scraggy spurs which merge on the border of the Sylhet and Cachar plains into a wild, jungle-clad tract of low hills.

Upper tertiaries.

The spurs and hillocks just mentioned are formed of upper tertiaries which attain enormous development in the area north-east of Jaintiapur. Their thickness in the Lubah valley cannot be less than 9,000 feet. They apparently rest upon the nummulitic limestone presently to be described, with perfect conformability, and are lithologically divisible into two subdivisions of which the lower consists of rather fine-grained, compact greyish and greenish-grey sandstones with interstratified shales. The upper division (well seen in the vicinity of Jaintiapur, Nichinpur, and Mulagul along the northern boundary of the Sylhet district) indicates shallow-water conditions, and is composed of false-bedded soft, greyish-white, rather massive and indistinctly bedded grits and coarse sandstones with subordinate darkish clays which often affect a nodular structure. In the sandstones by the Harry river below Nichinpur curious pockets (due probably to contemporaneous erosion) were noticed which are filled up with the clay just mentioned and with fine-grained compact sandstone.

Both these divisions are highly disturbed, but the disturbance is best seen in the lower of which good sections are exposed by the Nowagong, the Harry, and the Lubah rivers. The dip is seldom less than 35° and occasionally borders upon the vertical, and the strata are sometimes found to be folded. The dominant strike is E.N.E.-W.S.W. and the prevailing dip S.S.E.

Lower tertiaries, nummulitics.

The nummulitic limestone is absent at Sokha and Lamin near the Mangat, but is fairly well developed at Nongtalang (three miles east of Sokha). From the plateau it was traced eastwards through Umlotodo (Lakadong) to Narpo; and northward, in attenuated and interrupted development to near Pombadong (five miles north of Nongtalang) and to Umlawang (12 miles north of Narpo). As usual, its presence, where it occurs in any force, is marked by "Swallow holes" of various descriptions from small circular holes to enormous deep, thickly wooded chasms and glens which are mostly drained underground. At the foot of the plateau it is absent from Dowki on the Mangat, to Laikro (three miles north-east of Jaintiapur) having in all probability been denuded away. It, however, appears in great strength in the Harry valley at Barghat and Kharkhana, and continues eastward to the Lubah valley, where it swells and widens out considerably, and is superbly exposed, the weathered surface being generally thickly studded with fossils.

There are two distinct bands of limestone at Umlotodo aggregating some 250 feet in thickness, interposed between which occur some coarsish sandstones with carbonaceous layers.

Cretaceous rocks.

Sandstones referable to this system (internally greyish white and externally brownish and ferruginous) with shale intercalations in which carbonaceous layers are occasionally met with, have a very wide expansion east of the Mangat forming an extensive upland with rounded billowy undulations. They have usually a very coarse conglomerate at the base in which pebbles, mostly sub-angular and seldom well-rounded, are thickly and confusedly embedded.

This sandstone formation contains fossils consisting of echinoids and bivalves in some profusion and a sprinkling of gastropods and cephalopods were collected from them at Sokha and Lamin. Among the bivalves a species of *Ostræa* (*Alectryonia*) is the most prominent, having been met with in some abundance throughout the area. The lower series consists mainly of massive, coarse-grained, thick-bedded sandstones which are usually conglomeratic towards the base, the pebbles in the conglomerate being generally well-rounded and arranged in parallel layers. Fossils are very scarce, and, when found, occur towards the top just below the upper series. Thin films of coal are occasionally found in them; and at one place (in the ravines south of Lamin) nests and strings of fossilised resin were encountered.

The cretaceous strata rest with well-marked unconformity upon a much eroded surface of the older rocks.

Shillong series and gneissic rocks.

The Shillong series, which in the vicinity of Shillong consists chiefly of quartzites and quartzitic sandstones, passes into micaceous schists with occasional bands of well foliated gneiss when traced south-eastward to the Mangat valley; and this enhanced metamorphism is accompanied by increased disturbance.

Intrusive rocks. Granite.

Intrusions of coarsely crystalline massive granite with conspicuous well developed felspar were noticed in the Shillong series at several localities, as in the Mangat between Pompsao and Simunting, near Doarblai, etc. There is also a magnificent display of it in the Mangat valley at and above Darrang, as well as in the valley of the Rangapani between Nongtalang and Sawasdia. Further eastward, however, it is entirely missed. In the gorge of the Mantedu above

Barghat there occurs granite, but it is highly quartzose, fine-grained, and occasionally gneissose.

Dioritic rocks.

Dioritic intrusions occur in some strength in the Shillong series in the vicinity of Smit at the northern boundary of the Lailangkot-Nongkram patch of granite, and also near Doarblai.

4.—Punjab.

DERA GHAZ KHAN HILLS.
Mr. R. D. Oldham.

In the hills west of Dera Ghazi Khan the succession of rocks was found to be that described by Dr. Blanford, no additions of any importance having been made. As a result of more extended surveys it has, however, been possible to determine the horizon of the quartzites and limestone classed by him as cretaceous. The massive white quartzites when traced northwards are found to be the same as those forming the southern end of the scarp of quartzites in which the petroleum of the Sherani hills occurs. In the Sherani country Mr. La Touche found the belemnite shales underlying these quartzites and in the country surveyed by Mr. Oldham they are everywhere separated from the lower nummulitic shales by a band of pseudo conglomeratic limestone, which he regards as a crush conglomerate precisely similar to that which is found at the top of the Dunghan stage in the Mari hills of Baluchistan. These two horizons show that the quartzites of the hills west of Dera Ghazi Khan must be regarded as the equivalent of the Dunghan stage in Baluchistan, that is to say as bridging over the interval between upper cretaceous and lower eocene.

Indus river near Dera Ghazi Khan.

When passing through Dera Ghazi Khan Mr. Oldham took the opportunity of examining the records of the erosion of the Indus river at that place and is preparing a memoir on the subject which will be of considerable interest from a geological point of view, though no longer of any direct practical applicability to the protection of the city from the Indus. He finds in the annual river surveys and records of erosion that the river has behaved as it should have been expected to from certain little known principles first established in 1858 by the French engineer Dausse, which does not appear to have been known to the engineers in charge of the protective works. If the embankments built to prevent the escape of flood waters over the river banks are

maintained through the next flood season, it is probable that the river will leave Dera Ghazi Khan itself, but that the danger of its breaking away through the low ground to the west and devastating the district will be increased.

5.—Himalayan Ranges.

Parts of the KANGRA VALLEY *and* LAHOUL. *Mr. T. H. Holland.*

During the hot weather recess season, May to October 1901, Mr. T. H. Holland was deputed to the outer Himalayan ranges of the Kangra valley and Lahoul to fill in gaps in our geological maps of those parts. At the conclusion of the season Mr. Holland proceeded on a year's furlough, and as he has not yet been able to compile the results of his work, it would be premature to give extracts from his monthly diaries. He has, however, sent in a short report on the Kangra slate quarries which is being published, see page 19.

SPITI. *Mr. H. H. Hayden.*

Mr. Hayden proceeded to Spiti early in June 1901 in order to complete the survey of that area, which had been interrupted since 1899, and he has now brought up the task to a certain degree of completeness. This will form the subject of a memoir now being prepared by Mr. Hayden in which he was to have been assisted by the late Dr. von Krafft, who had accompanied him to Spiti in 1899 and had worked out the mesozoic rocks in considerable detail, but whose sad death in the autumn of last year has deprived us of much of the fruit of his valuable and conscientious work.

During the past season Mr. Hayden devoted most of his time to working out the palæozoic rocks of Spiti and Kanaur.

Further collections which were made from the silurian beds underlying the white (Muth) quartzite, have added considerably to our knowledge of the extent of this system, which appears to embrace the whole of the series found in Spiti between the base of the red quartzite and the base of the white (Muth) quartzite, specimens of *Pentamerus oblongus*, Sow., having been found in the silicious limestone immediately underlying the latter bed.

In Kanaur the system of limestone, shale and quartzite, so well exposed between the Lipakaw and Yulang rivers, was examined in greater detail than had hitherto been possible and large collections of fossils

were made. These have been partly worked out, and have been found to include numerous widely distributed carboniferous types, such as *Syringothyris cuspidata*, Mart., *Athyris roysii*, Leo., *Strophomena analoga*, Phill., *Athyris subtilita*, Hall, *Rhynchonella pleurodon*, var. *davrenxiana*, Kon., *Reticularia lineata*, Mart., *Productus semireticulatus*, Mart., *Productus cora*, d'Orb., *Chonetes hardrensis*, Phill., and many other forms.

Further collections were also made from the permian beds near Po, in Spiti, but these have not yet been worked out. While in Spiti, Mr. Hayden's attention was drawn by the late Dr. von Krafft to the fact that the triassic horizon of *Rhynchonella griesbachi*, Bittner, had not been identified in Spiti, though large collections had been made from it in the eastern Himalayas. A careful search proved that the species occurs also in Spiti, but fossils are extremely rare; several specimens, however, of *Rh. griesbachi* were obtained. This horizon had hitherto been looked upon as the base of the muschelkalk, but Mr. Hayden has now found both in and above it ammonites of lower triassic age, and this view must therefore be modified.

During the search for the horizon of *Rhynchonella griesbachi*, a bed was found some few feet lower down containing numerous specimens of *Pseudomonotis himaica*, Bittner. The relative positions of these two horizons had not hitherto been known with any certainty, but these have now been definitely ascertained.

6.—Baluchistan.

Mr E. Vredenburg.

Mr. Vredenburg remained in Baluchistan up to the end of September 1901, after which he returned to Calcutta to classify his extensive collections of rocks, minerals and fossils, the result of nearly a whole year's field-work.

A short notice appeared in the last "General Report" dealing with the work performed in the Nushki desert up to March 1901. April and May were spent in mapping the tertiary igneous intrusions of the Khwája-Amrán, mostly granites and diorites. The rest of the season was occupied in the detailed mapping of the upper Zhob and some adjoining areas of the Pishin district, thus filling up the largest gap that still remained in the geological map of eastern Baluchistan, as many parts of that area were either completely unknown or had been visited only during rapid traverses. Last year's survey

has yielded some very interesting results, foremost amongst which may be mentioned the delineation of a large outcrop of upper trias. The rocks of that age consist of a system of shales converted by cleavage into slates, interbedded with narrow bands of a dark, nearly black limestone. Their outcrop, which is considerable, occupies the southern side of the upper Zhob valley. Owing to some lithological resemblance, they were formerly regarded as identical with the Kojak shales which occupy the Toba highland and its eastern continuation north of the Zhob, although Mr. Oldham, in the second edition of the Manual, had already expressed doubts as to the correctness of grouping together the rocks on either side of the Zhob valley. I myself, when surveying in Baluchistan in 1893, found numerous species of *Monotis* sp. and an ammonite, described by von Mojsisovics as *Didymites afghanicus* in the Palæontologia Indica, and this proved that Baluchistan contained horizons of the upper trias. It was not practicable to trace the origin of those fossils at that time, and I had to regard them as perhaps mere "blocs exotigues" caught up in a complex of later age. The work done by Mr. Vredenburg last year has established beyond the possibility of a doubt that the fossils were derived from the shales themselves. These fossils are scanty and poorly preserved, but widely distributed, and have been found *in situ* in every possible situation throughout the outcrop which is at least 50 miles long and in some places 12 miles broad. There must be a considerable thickness of these shales, but, as the commonest fossil is everywhere the same one, it is probable that we are in presence of a single stage of the trias, powerfully developed, and repeated many times by folding. The closely folded and crushed state of the rocks probably accounts largely for the scarcity of fossils.

Side by side with the *Monotis* bearing slates, there are some very limited outcrops of *fusulina* limestone of carboniferous or permian age which I had already noticed in 1893. The lithological sameness and great amount of disturbance conceal the nature of the contact, which is perhaps a faulted one.

Great basic and frequently serpentinised intrusive masses, partly the core of a cretaceous volcano, break through these older rocks and have been often referred to as representing the Deccan trap eruption of the Peninsula. These and the triassic rocks formed a land surface during a considerable part of the eocene period: the tertiary often begins only with the Spintangi which rests upon them either directly

or with the intervention of the upper portion of the Gházij. When these rocks rest upon the basic intrusions, the latter are found to have been converted into laterite down to a considerable depth.

In a number of localities, there intervene between the Spintangi and the lower Siwaliks, a group of variegated beds unconformable to the former and containing fossiliferous limestones in their upper portion. In consideration of their unconformable stratigraphy, as well as for lithological and palæontological reasons, Mr. Vredenburg is of opinion that these beds belong to the upper Nari. The fauna contains a number of lower Nari species, but some of the most characteristic ones are absent, while other species are identical with fossils occurring in the Gáj of Sind or the miocene of Europe. Amongst them may be mentioned *Breynia carinata*, d'Arch. and H., *Pecten favrei*, d'Arch. and H., *Trochus cognatus*, J. de C. Sow. (= T. *lucasanus*, Brongn.) all typical Gáj species in Sind, *Nerita martiniana*, Math., frequent in many oligocene and miocene strata of Europe, *Lucina columbella*, Lam., which is one of the commonest miocene form in Europe; the latter being extremely abundant in some exposures. Nummulites which are so abundant in the lower Nari are completely wanting. Dr. Noetling in common with other palæontologists is of opinion that the lower Nari formerly regarded as oligocene cannot be maintained in that formation as restricted by many geologists, but should be classed as eocene. It is not unlikely that the strata discovered in Baluchistan correspond with some of the beds which, by common assent, are regarded in Europe as true oligocene. It may be mentioned here that the true lower Nari, with its characteristic nummulites, occurs in several parts of Baluchistan. Dr. Blanford found it in the Bolan pass, and Dr. Noetling met with another outcrop in the northern Zhob. In the latter instance, in the neighbourhood of Tanishpa, Dr. Noetling also discovered a higher fossiliferous horizon without nummulites, which may belong to the miocene Gáj. It seems closely related to the group described by Mr. Vredenburg, several peculiar species being common to both.

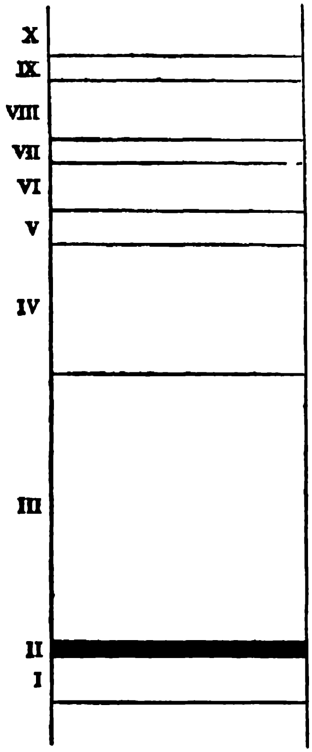
7.—Sind.

Mr. Vredenburg.

On his way to Baluchistan, Mr. Vredenburg spent the month of March of the present season in Sind, in continuation of some of the work performed two years ago. As a result of the study of the rich fossil collections both

from Sind and from Baluchistan preserved in the Calcutta Museum, Dr. Noetling and Mr. Vredenburg have found it necessary to introduce some further corrections in the tables of strata published in the two last "General Reports" The sequence of beds remains unaltered, but it is necessary to restore the names Ranikot and Khirthar to the position originally assigned to them by their author. The terms Ranikot and Khirthar were first employed by Dr. Blanford to designate two well-marked divisions in the eocene of Sind, the former of the two being known only in some parts of southern Sind. In many parts of Baluchistan, the eocene is easily subdivided into two groups, the Gházij and Spintangi, and it has been repeatedly suggested that this twofold division may correspond with that originally made in Sind. It is only fair to state that these suggestions were generally made in reports written in the field without any opportunity of a direct comparison of the fossils. Whenever these came to be carefully studied, the differences between the Gházij fauna and the Ranikot one became obvious, though it still remained to be proved that it was anything else but a difference of facies, and there remained a general idea that the two groups might be vicarious. The true equivalent of the Gházij had long ago been found in Sind in the richly fossiliferous shaly strata which, in the Laki range, occur near the top of the Khirthar, but, owing to the supposed identity of the Gházij and Ranikot, this group remained overlooked in all the comparisons that were made until attention was drawn to the fact by Dr. Noetling. When Dr. Noetling first came across these shales near the sulphur springs at Laki, he recognised at once their complete identity with the Gházij, and, following the accepted notion of the identity of the Gházij and Ranikot, he looked upon them as an inlier of the latter. This explains why, in the lists of strata published in the two last "General Reports," the upper limit of the Ranikot has been placed higher than it originally was by Dr. Blanford. It was only during subsequent progress of their work that Dr. Noetling and Mr. Vredenburg came across fossiliferous exposures of the true Ranikot. It then became evident that the upper limit of the Ranikot is situated several hundred feet below the Laki shales which are near the top of the Khirthar.

The following column shows the succession of strata in the Laki range, the different divisions being rendered approximately proportionate to their relative thicknesses.



I.—Shales and sandstones with some bands of limestone containing *Cardita beaumonti*, zones 2 and 3 of the previously published lists.

II.—Deccan trap, zone 4.

III.—Ranikot series, as originally defined. In the Laki range it consists almost entirely of sandstones which are either quite unfossiliferous, or contain only imperfect plant remains. At the base, resting on the Deccan trap, there frequently occurs an oyster bed, zone 5. The uppermost portion is sometimes fossiliferous, containing the new genus and species of zone 7. This curious species occurs also in the *Cardita beaumonti* beds, both in Sind and in Baluchistan.

IV.—Principal mass of the Khirthar limestone, zone 9. The fossils usually weather out as casts except in the lowermost beds which constitute zone 8, *of Macropneustes speciosus.*

V.—Shales, clays and impure limestones, constituting zones 10 to 13 of previously published lists. Dr. Noetling has shown that these correspond with the Gházij of Baluchistan.

VI.—Limestone with large *nummulites*, uppermost part of the Khirthar, zone 14. This corresponds with the Spintangi of Baluchistan.

VII.—Mostly clays in which are intercalated some bands of dark brown richly fossiliferous nummulitic limestone, zones 15 to 17. This is the lower Nari.

VIII.—Variegated sandstones and clays, probably upper Nari.

IX.—Fossiliferous strata between the top of the variegated beds and the base of the Manchhars. Near Bagathoro the lowermost bed contains an admixture of Gáj and Nari species, together with some

peculiar species occurring in the strata regarded as upper Nari in Baluchistan and not found in any collections from the lower Nari or the typical Gáj of Sind; amongst them are *Lucina columbella* and *Nerita martiniana*. These are probably nearly of the same age as the fossiliferous beds classed as upper Nari in Baluchistan. The general appearance of the fauna recalls the presumed Gáj of Tanishpa. Above this bed, a slightly calcareous sandstone, are some limestones with typical Gáj forms such as *Echinodiscus* and large specimens of *Ostrea blanfordiana*, Noetl. Higher again comes a bed full of large specimens of *Ostrea lingua*. This bed is frequently met with at the base of the Manchhars.

X.—Base of the lower Manchhars which resemble lithologically the lower Siwaliks of Baluchistan. The lowermost beds contain vertebrate remains.

Neither the top of the Ranikot nor the base of the Khirthar are present in the above described section. It is doubtful how far the Ranikot and Khirthar are ever truly conformable, but there is an undoubted break, far more pronounced than elsewhere, in the Laki range, as was already pointed out by Dr. Blanford. Further south an important series of highly fossiliferous strata overlie zone 7 of gen. nov. spec. nov., and underlie the true Khirthar. *Nummulites* make their appearance in great abundance in these beds which, in the neighbourhood of Jhirak, contain an abundance of true *blemnites* side by side with the *nummulites*. Their mode of occurrence precludes all possibility of their being derived from an older stratum; the horizon of gen. nov. spec. nov. is not exposed at Jhirak where the lower part of the fossiliferous series is hidden beneath the Indus alluvium. At Meting, west of Jhirak, the zone 8 of *Macropneustes speciosus* is easily traceable, but it is underlaid by other Khirthar zones rich in specimens of echinoid species, none of which pass downwards into the true Ranikot. Many of the Khirthar species described in the Palæontologia Indica were obtained from the horizons underlying the zone of *Macropneustes speciosus*. Amongst the more abundant may be mentioned *Porocidaris anomala*, D. and S., *Rhynchopygus calderi*, d'A. and H., *R. pygmæus*, D. and S., *Hemiaster digonus*, d'Arch., *Metalia sowerbyi*, d'Arch. In this neighbourhood where the upper beds of the Ranikot and the lowest of the Khirthar attain their greatest thickness, the separation of the two is still well marked by a ferruginous bed of laterite, and it is doubtful whether even here there is a truly uninterrupted sequence.

One result of extreme importance is the following: it is now certain that, whilst strata of the age of the *Cardita beaumonti* beds are widely distributed in Baluchistan, the Ranikot series is absolutely unknown outside a comparatively small area of lower Sind. It is highly probable that the Ranikot beds are amongst the oldest strata yet discovered in any country that can be safely classified within the tertiary system.

An error that crept into the General Report for 1900-1901 may be corrected here. In mentioning the interesting occurrence of tertiary *belemnites* above alluded to, near Jhirak, on page 5 of that publication, the discovery was attributed to Dr. Noetling. The original finder was Mr. Vredenburg.

Blown sand at KARACHI.
Mr. R. D. Oldham.

When passing through Karachi Mr. Oldham found an opportunity of investigating the question of the sandhills which are blocking the road from Karachi to Clifton. The growth of these sandhills has been rapid during the last few years, but no accurate data are available, a survey has now been made which will enable their progress in future to be measured. The cause of the sandhills is locally supposed to be the dumping of dredgings from the harbour of Clifton. This appears to be an unimportant factor compared with the general drift of sand along the shore; the direct cause is the closing of one of the original outlets of the Karachi harbour, known as the Chinna creek, by which the tidal scour that kept the foreshore of the Clifton cliffs free from sand has been checked. An accumulation of sand has consequently been formed which stretches out beyond the former shore line and has formed a gathering ground from which the sand has been blown inwards by the strong winds of the monsoon. There appears to be no practicable cure, for the reopening of the Chinna creek is out of the question on account of the deterioration of the harbour which would result, and the only palliation possible appears to be the encouragement of the growth of the local couch-grass.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

CALCUTTA:
The 1st April 1902.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE YEAR

1902-1903.

BY

T. H. HOLLAND, A.R.C.S., F.G.S.,
Director.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1903.

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CONTENTS.

ADMINISTRATION LIST.

Director.

Mr. C. L. Griesbach held the office of Director until the 24th February 1903, when he retired and was succeeded by Mr. T. H. Holland.

Superintendents.

1. Mr. R. D. Oldham, A.R.S M., F.G.S.
2. Mr. T. D. LaTouche, B.A., F.G.S., on privilege leave for 28 days from 8th September to 5th October 1902.
3. Mr. C. S. Middlemiss, B.A., F.G.S.

Deputy Superintendents.

1. Mr. P. N. Bose, B.Sc. (Lond.), F.G.S.
2. Mr. T. H. Holland, A.R.C.S., F.G.S., returned from combined privilege leave and furlough on the 29th January 1903. Appointed Director from 25th February 1903.
3. Mr. P. N. Datta, B.Sc. (Lond.), F.G.S.
4. Mr. F. H. Smith, A.R.C.S., F.G.S.

Assistant Superintendents.

1. Mr. H. H. Hayden, B.A., B.E., F.G.S., promoted to Deputy Superintendent with effect from the 25th February 1903, and vacated office of Curator from the 6th March 1903.
2. Mr. E. Vredenburg, B.L., B.Sc. (Paris), A.R.C.S., appointed Curator of the Geological Museum with effect from the 7th March 1903.
3. Mr. L. L. Fermor, A.R.S.M., F.G.S., joined in India 29th October 1902.
4. Mr. G. E. Pilgrim, B.Sc. (Lond.), joined in India 29th October 1902.

Palæontologist.

1. Dr. F. Noetling, Ph.D. (Berlin), F.G.S.

Mining Specialists.

1. Mr. R. R. Simpson, B.Sc., Officiating Inspector of Mines up to 18th December 1902, reverted to his appointment as Coal Specialist on the 20th December 1902.
2. Mr. J. M. Maclaren, B.Sc., F.G.S., joined in India 29th October 1902.

Sub-Assistants.

1. HIRA LAL, on privilege leave for 34 days from 1st September 1902
2. KISHEN SINGH, F.G.S., on sick leave from 27th January 1902.

Artist.

1. MR. H. B. W. GARRICK, on privilege leave for 1 month and 4 days from 1st September 1902.

Assistant Curator.

1. MR. T. R. BLYTH.

Registrar.

1. MR. A. E. MACA. AUDSLEY, on sick leave for 9 months from 7th May 1902.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE YEAR

1902-1903.

PART I.—HEAD-QUARTER NOTES.

1.—Retirement of Mr. C. L. Griesbach.

1. Although this report is written and signed by his successor, eleven-twelfths of the work it reviews was carried out, and the whole of it organized, under the direction of Mr. C. L. Griesbach, C.I.E., whose term of office expired on the 24th February, when he retired under the 55 years' rule.

Mr. Griesbach, in the interests of the work of the Department, has deprived me of the convenient instrument which he himself possessed in the *Records* for reviewing his predecessor's services, when he took over charge of the Department from the late Dr. King in 1894. But whilst attempting to make this report a faithful expression of his last year's work in India, and the final contribution to his record of official activity for over 24 years, I would like to take the opportunity of expressing the hope that in his retirement from the service, but not from geological work, he will receive further signs of the appreciation with which scientific societies in Europe have already marked the work done during his official career in India.

2.—Appointments.

2. The gaps in the officers' list caused by the loss of Drs. Walker and von Krafft and Mr. Stonier, referred to in the last General Report (p. 2), have been repaired by the appointment of Messrs. L. L. Fermor, G. E. Pilgrim, and J. M. Maclaren, who arrived in India on the 29th October.

3.—Director's Tours.

3. During the year under report, Mr. Griesbach made the following tours:—

In May he visited Shillong to inspect the work carried on by Mr. Bose during the previous field season. During September he visited Kashmir and inspected the localities in which Dr. Noetling had found Gondwana plants associated with permian marine strata (*infra*, p. 22).

Mr. Holland made a tour through the coalfields of Raniganj, Jherria, and Giridih during February.

4.—Museum and Laboratory.

4. Mr. H. H. Hayden was in charge as Curator throughout the year, and, in spite of the want of a subordinate staff for work in the galleries, appears to have made satisfactory progress in labelling the collection which has been displayed in the show-cases. The collection of fossils, arranged in zoological order in the wall-cases of the palæontological galleries, were cleaned and re-labelled throughout, and a further portion of the Indian rocks in the lower gallery provided with printed labels.

5. The collection of minerals has been largely augmented by the addition of examples of a number of new and rare species obtained by purchase. As a reference collection the minerals now displayed are worthy of the creditable position which the Indian Museum now admittedly takes amongst the metropolitan museums of the world. The meteorite collection has been enriched by the addition of eight falls not previously represented, bringing the total number of meteorite falls up to 380.

The way in which the Museum is intelligently valued by the public is shown by the complete exhaustion of every edition of the guides which have been prepared by officers of the Geological Survey.

6. Much of the time of the Curator and his Assistant was taken up with the routine determinative and analytical work on specimens sent by other departments and the officers in the field: in this and in the work of the Museum the Curator reports that he has received from the Assistant Curator the same efficient assistance which has characterised every year of Mr. T. R. Blyth's service.

7. The following donations have been received during the year:—

A specimen of galena, from Erki, 20 miles from Simla.

Presented by Capt. Bernard Scott, I.A.

A specimen of asbestos, from near Sejavada, Alirajpur State, Bhopawar Agency, Panch Mahals.

Presented by Balkrishna C. Joshi, Godhra.

Specimens of the Barratta and Gilgoin station aerolites, found in 1845 and 1889, weights 506 grams and 189 grams; and of the Tucson (Arispe) siderite, found in 1850, weight 287 grams.

Presented by Prof. H. A. Ward, Chicago.

A specimen of the Mount Joy siderite, found in 1887, weight 1,240 grams.

Presented by the K. K Naturhistorisches Hof-Museum, Vienna.

Numerous specimens of bi-pyramidal quartz crystals, from limestone quarries at Katni, Jabalpur district.

Presented by H. F. Cook and Sons, Katni, E. I. Railway.

A specimen of the Bjurböle aerolite, which fell 12th March 1899, weight 27 grams.

Presented by the K. K. Naturhistorisches Hof-Museum, Vienna.

A large specimen of copper pyrites from the Rajdoha Mining Company's "Gladstone" shaft, 233-foot level, Rakka, Chota Nagpur

Presented by Gillanders Arbuthnot & Co., Calcutta.

5.—Palæontological Work.

(a) DESCRIPTIVE WORK IN INDIA.

8. The progress in descriptive palæontology at head-quarters has been interrupted by the absence of the Palæontologist in the Simla district and Kashmir from April to October and in the Salt Range of the Punjab from November to March.

9. During the last recess, however, Mr. E. Vredenburg undertook the preparation of a catalogue of the Tertiary *Foraminifera* from

Sind and Baluchistan, paying special attention to the *Nummulites*, which are, on account of the way these peculiar forms became spread all over the great central ocean, stretching from Europe to South Asia in early Tertiary times, of unusual assistance in correlating the Lower Tertiaries of Sind and Baluchistan with those of the standard scale of Europe. Taking eight of the more important species which are common to Europe and India, we have the following correlation scale for the Nummulitic formations in the Sind-Baluchistan area :—

Correlation of Nummulite-bearing beds of Western India.

Sind and Baluchistan.	European Stages.
LOWER NARI with *N. intermedia*	Priabonian.
Unconformity	Bartonian.
UPPER KHIRTHAR (with the Ghazij and Spintangi of Baluchistan) containing *N. perforata*, *N.* (*Assilina*) *granulosa*, *N.* (*Ass.*) *exponens* . . .	Lutetian.
LOWER KHIRTHAR with *N. biarritzensis* and *N.* (*Assilina*) *placentula*	
Unconformity	
UPPER RANIKOT—	Ypresian and Sparnacian.
Zone 4 with *N. planulata* and *N.* (*Assilina*) cf. *nili*	
Zone 3 with *N.* (*Assilina*) cf. *nili* . . .	
Zone 2, Zone 1 } without Nummulites . . .	

(*b*) Descriptive Work in Europe.

10. Of the palæontological work done in Europe the only results received during the year are embodied in an important memoir by Prof. Carl Diener, giving a description of the permian fossils collected in the Central Himalayas by Messrs. LaTouche, Smith, Hayden, Walker, and von Krafft during 1898—1900. The memoir, amounting to 214 pages of the *Palæontologia Indica*, is now in the press. The additional details made available by this exhaustive work tend to accentuate the distinction in facies between the normal permian rocks of the Central Himalayas and the permian blocks which have been brought from some unknown region, and left as isolated crags on the younger strata. The permian fossils in these exotic blocks show greater affinities with the Salt Range permian than with the strata of the same age in the Central Himálayas.

6.—Publications and Library.

11. The following publications were issued during the year:—

General Report on the work carried on by the Geological Survey of India, from the 1st April 1901 to the 31st March 1902.

Memoirs, Volume XXXII, Part 3. Notes on the "Exotic Blocks" of Malla Johar in the Bhot Mahals of Kumaon, by A. von Krafft.

Memoirs, Volume XXXIII, Part 2. Title-page, contents, etc.

Memoirs, Volume XXXIII, Part 3. The Geology of Kalahandi State, Central Provinces, by T. L. Walker.

Memoirs, Volume XXXIV, Part 2. The Mica Deposits of India, by Thomas H. Holland.

Memoirs, Volume XXXV, Part 1. Geology of Western Rajputana, by Tom D. LaTouche.

Palæontologia Indica, Series XVI, Volume I. Title-page, contents, etc.

Palæontologia Indica, New Series, Volume II, Article 1. Observations sur quelques plantes fossiles des Lower Gondwanas, par R. Zeiller.

Library.

The additions to the Library during the year 1902-03 amounted to 2,017 volumes, of which 1,184 were acquired by presentation and 833 by purchase.

7.—Disposition List.

12. During the year ending the 31st March the officers of the Department were posted as follows:—

SUPERINTENDENTS.

Mr. R. D. Oldham . .	At head-quarters till November 11th; posted to Upper Burma, Lower Chindwin and Pakoko districts. Returned to head-quarters February 3rd, and left for Jammu March 21st.
Mr. T. H. D. LaTouche .	Returned to head-quarters from the Northern Shan States on the 20th May 1902 On privilege leave from 8th September to 5th October 1902. Deputed to examine the Ladda coal-field, and returned to head-quarters on the 8th November 1902. Posted to Burma from the 11th November 1902, and returned to head-quarters on the 20th March 1903.
Mr. C. S. Middlemiss .	Returned to head-quarters from the Vizagapatam hill tracts on the 10th May 1902. Posted to the same area from the 1st November 1902 to date.

DEPUTY SUPERINTENDENTS.

Mr. P. N. Bose . .	Returned to head-quarters from Assam on the 11th June 1902; and left Calcutta for the field on the 22nd October 1902 to continue his survey of the Jaintia hills of Assam.
Mr. P. N. Datta . .	Returned from the Northern Shan States on the 26th May 1902. Posted to the same area, and left for the field on the 4th November 1902.
Mr. F. H. Smith . .	Returned to head-quarters from Chota Nagpur on the 3rd May 1902. Posted to the same area on the 5th November 1902.
Mr. H. H. Hayden . .	At head-quarters throughout the year.

ASSISTANT SUPERINTENDENTS.

Mr. E. Vredenburg . .	Returned from Baluchistan on the 10th June 1902. Left on 3rd November to make a survey of the Dhar State.
Mr. L. L. Fermor . .	Joined the Department 29th October 1902. Deputed to accompany Mr. Vredenburg on the 3rd November 1902.
Mr. G. E. Pilgrim . .	Joined the Department 29th October 1902. Deputed to accompany Mr. LaTouche on the 11th November 1902.

PALÆONTOLOGIST.

Dr. F. Noetling . .	Deputed to the Dargoti State, north-east of Simla, on the 22nd April 1902. On completion of this special examination, was posted to Kashmir. Returned to head-quarters on the 23rd October 1902, and left on the 3rd November to accompany Professor E. Koken during his visit to the Salt Range and Siwaliks, and returned to head-quarters on the 5th March 1903.

SPECIALISTS.

Mr. R. R. Simpson . .	Deputed to examine the coal of the Trans-Indus range, Mianwali district, also to the Jammu territory, and left on the 14th January 1903.
Mr. J. M. Maclaren . .	Joined the Department 29th October 1902. Posted to Chota Nagpur and left Calcutta for the field on the 7th November 1902.

SUB-ASSISTANT.

Hira Lal . . .	During the field season 1902-03 was attached to Mr. Smith's party in the Chota Nagpur division.

ASSISTANT CURATOR.

Mr. T. R. Blyth . .	Was on duty at head-quarters throughout the year.

PART II.—FIELD-WORK.

A.—*ECONOMIC ENQUIRIES.*

1.—Coal.

ASSAM: SHILLONG PLATEAU: *Mr. P. N. Bose.*

13. Towards the close of the season 1901-1902, and after the submission of the report covering the work up to the 31st March, Mr. Bose discovered some rolled fragments of coal in a stream about 4 miles west of Barapani, near Shillong. On resuming field work this season, he followed up this discovery, and successfully traced the origin of the coal to some outcrops situated close to the head-waters of a stream known as the Um Rileng at the foot of Dinghie hill, about 2 miles west of the Shillong-Gauhati cart-road. The outcrops are much concealed by jungle and superficial deposits, but a systematic search and prospecting operations laid bare a fairly good section, in which several horizons of good coal were found, the most important seams of which are two of 4 feet and 6 feet 6 inches thickness, respectively.

14. Assays of two samples made in the Laboratory showed the coal to be of good quality, and its position—within 11 miles of Shillong and only 2 miles from the Shillong-Gauhati cart-road—warranted the institution of a careful exploration of the field. The work of testing the resources of the field was undertaken by the Public Works Department with the assistance of advice from Mr. Bose. Two pits, put down at selected distances from the outcrop, in the hope of meeting the seams and thus proving the horizontal extension of the coal, reached, respectively, 28 and 21 feet, when difficulties arose from the influx of water, and it was decided to continue the test by boring. Matters were at this inconclusive stage at the close of the season, and an attempt will, I hope, be made to carry out the work more energetically during the present year.

MIANWALI DISTRICT, PUNJAB: *Mr. R. R. Simpson.*

15. During January Mr. Simpson undertook the examination of the coal deposits in the Isakhel tahsil of Mianwali district, Punjab. Four groups of deposits were examined, which may be distinguished as—

(1) Kálabágh area
(2) Kuch area.
(3) Between Kuch and Sagruto summit.
(4) Mulla Khel and Sultan Khel area.

16. The Kálabágh coal deposits were found to be very variable in quality and thickness of workable seams, and the estimate of about 50,000 tons of available fuel is based on the assumption that an average thickness of 4 feet would be maintained over the strike of 550 feet. At Kuch, about 6 miles further north and less favourably situated for transport to the Indus, a rough estimate was made of 11,000 tons of available coal for a seam averaging about 16 inches in thickness. The coal-seams opened by drives in the ground between Kuch and the Sagruto peak are not considered to be worth working.

17. A more promising result was obtained in the fourth area examined. From the outcrop seen in the Barochi gorge about 2 miles north of Mulla Khel, a seam, varying from 1 to 4 feet in thickness, was traced for about 6 miles to the south to a point west of Sultan Khel. Samples taken from this seam, and from the three other areas, are now being examined in the Laboratory, and when the assays are complete a report will be submitted on the probable value of, and best method of attacking, these deposits.

2.—Chromite.

Baluchistan: Mr. E. Vredenburg.

18. In April 1902 Mr. Vredenburg proceeded from Sind to Baluchistan and examined the chrome-iron ore deposits in the Pishin and Zhob districts. The chromite occurs as veins and irregular, segregated masses in the serpentines that accompany the great basic intrusions of upper cretaceous age, which form particularly conspicuous masses amongst the hills bordering the Upper Zhob valley, both to the north and south. To the westward these serpentines continue into the upper valley of the Pishin river, which forms the geographical and geological continuation of the Upper Zhob, while to the east and north-east a few observations made at different times by various geologists indicate their continuation at intervals along the Lower Zhob, and even as far as the Tochi valley.

19. One of the most promising localities occurs about 2 miles east of Khánozai in the Pishin district, where Mr. Vredenburg specially investigated a vein-like mass about 400 feet long with an average breadth of 5 feet. The vein consists of almost pure ore of great richness. An analysis made in the Laboratory of the Geological Survey gave over 54 per cent. of chromium sesquioxide, and some parts of the vein show even a higher percentage. The locality is connected by an excellent road with Khanai railway station, 17 miles distant.

3.—Fire-clay.

ASSAM: *Mr. P. N. Bose.*

20. The fire-clay previously noticed by Mr. Bose near Jowai was, at the request of the Honourable the Chief Commissioner of Assam, re-examined and sampled for testing. The tests, kindly made by Messrs. Burn & Co., show that the material forms excellent fire-bricks capable of standing a great heat. Its occurrence in large quantity in the vicinity of good coal makes it available for the manufacture of bricks, against which there appears to be only the cost of transport to a market.

4.—Gold.

CHOTA NAGPUR: *Mr. F. H. Smith. Mr. J. M. Maclaren. Hira Lal.*

21. On account of the numerous statements which have been made in the past about finds of gold, and of the occurrence of ancient gold-workings in Chota Nagpur, a survey of the most prominent parts of the division was instituted in the season 1901-1902 by Mr. Smith and Hira Lal, and was continued during the past season with the addition of Mr. J. Malcolm Maclaren to the party. The details of these investigations will be published in a special memoir now being prepared by Mr. Maclaren.

22. The area examined covers parts of the districts of Mánbhúm and Singhbhúm, with the tributary states of Gangpur, Bonai, Údepúr, and Jashpúr. The distribution of the geological formations, as corrected up to date, is shown in the accompanying map (fig. 1). The large area marked as Dharwarian consists of a group of imperfectly foliated schists and phyllites, similar in general characters to the Dharwar series in South India, and, like them, much older than the oldest unfossiliferous rocks distinguished as the Cuddapahs. A prominent and important feature in the country is the great Dulma band of dioritic trap which runs from south of Dhadka, in Mánbhúm, into Western Singhbhúm, has affected all the rocks in its neighbourhood, and appears to be responsible for the auriferous character of the quartz veins, as all the instances of gold found *in situ*, have been in close proximity to the Dulma trap, or to dykes of a similar petrological character. The most conspicuously auriferous horizon in the Dharwar series is a little south of the Dulma trap-band, just outside the zone of pronounced thermal metamorphism, and, judging by the distribution of alluvial gold at Patkum and in Mánbhúm, a similar auriferous

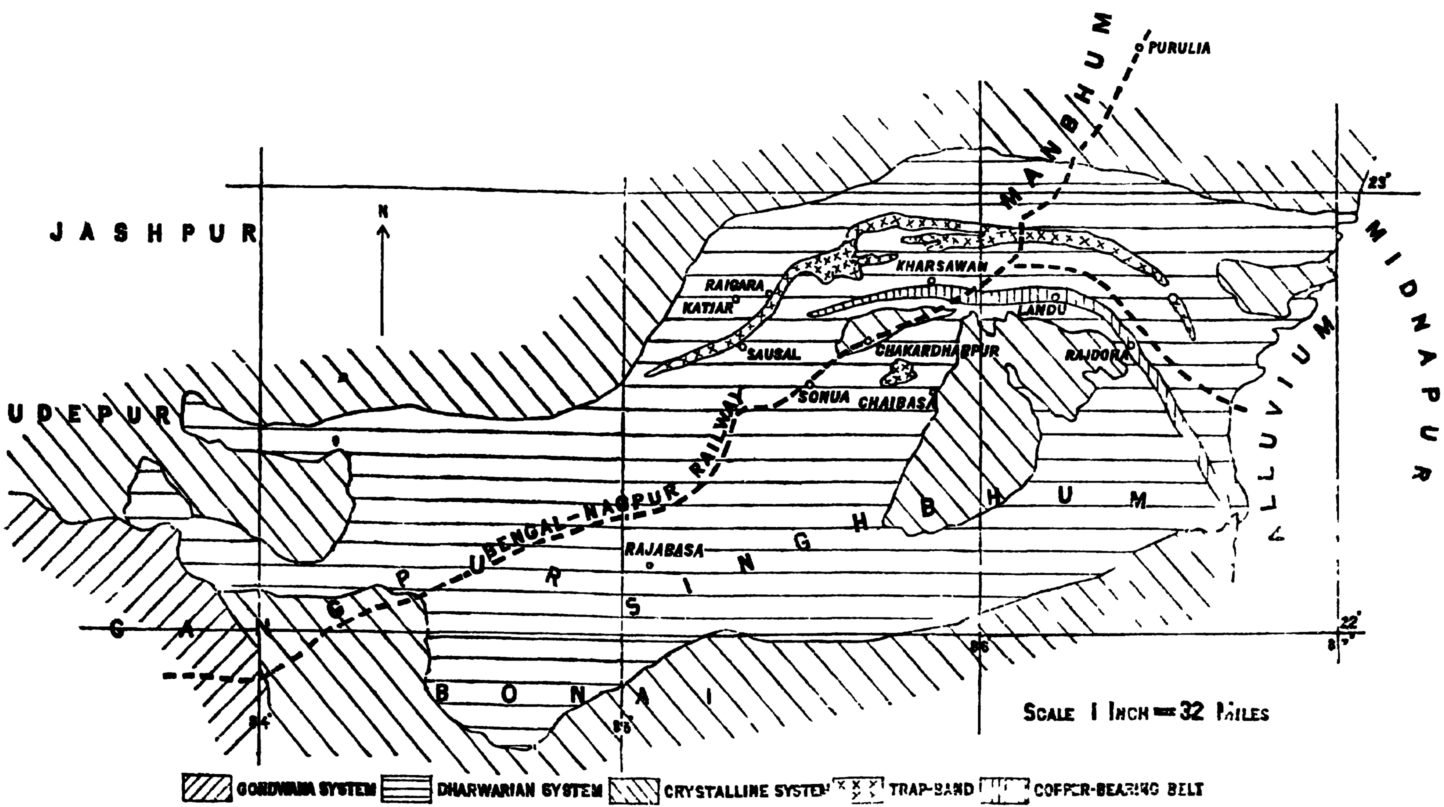

FIG. 1.—*Geological Map of the Chota Nagpur auriferous belt.*

horizon exists to the north of the trap. The well-known copper-bearing zone, shown on the map further south, was not subjected to special study, the work being confined to testing the resources of the country in gold.

23. Gold being a metal of very wide distribution and one which can be profitably worked in rocks carrying such small quantities, one is never safe in assuming from a few scattered observations that it certainly does not exist in payable quantities in any area of crystalline rocks. In the case of Chota Nagpur, without asserting that payable gold deposits do not *possibly* exist, the results of the present enquiry have not included a single instance which could be reasonably regarded as a legitimate mining proposition.

Auriferous reefs.

24. With regard to the quartz reefs, the deposits are thin and their mineral contents "patchy," so much so, that instead of expressing the richness in ounces per ton, the ore bodies are so small that they might more appropriately be expressed as grains to the ounce of quartz. The full report will show that the operations conducted by the survey party did not extend to any depth. But the common fallacy that an auriferous vein necessarily improves with depth has not been allowed to divert the party from the policy of making superficial examination of many outcrops instead of deeply prospecting a few.

25. In the course of the survey, two doubtful prospecting propositions were discovered, that is, two areas where, on commercial principles, further search for auriferous veins may be regarded as a justifiable venture. These are (1) the range between Ankva and Manharpur, and (2) the line lying about 3 miles south of the Dulma trap, connecting Sausal and Sonapet. The first is mentioned on account of the rich, coarse, alluvial gold found in the immediate vicinity, of the rich specimen of auriferous quartz picked up in the Ankua stream, and of the existence of large, well-defined quartz reefs in the neighbourhood. Along the second area nearly all of the gold hitherto found *in situ* in this division has been obtained.

Alluvial gold.

26. The recovery of gold from alluvial deposits offers no brighter prospects than that of mining the quartz-veins. Hydraulic mining, as practised in other countries, is out of the question, on account of lack of water and the poverty of gold content. At Sonapet conditions for the storage of water on a large scale, and under sufficient head, are extremely favourable; but the result of trials indicated the average gold content to be less than 1½ grains per cubic yard; and, considering the large capital outlay

necessary, this amount is far too small to give any hope of profitable return. At Ankua, also, water could be obtained at no great cost, but the gold content here is only about ½ grain to the cubic yard—even lower than that of Sonapet. It has been suggested that the richer gravels, at least, could be shifted at a profit to suitably situated tail-races by coolie labour, but, though this may be possible for dry gravel, the handling of gravel full of water would hopelessly handicap the undertaking.

27. The suggestion to undertake dredging operations has also been kept in view; but the conditions of the Chota Nagpur rivers introduce difficulties not usually encountered in successful dredging operations. Most of the rivers flow over the hard, upturned edges of schistose rocks, which, as in the Súbanríkha, form a succession of rocky bars across the stream, between which native workers wash for gold. Operations would necessarily be intermittent on account of the annual floods, and with each flood the layer of "wash" stripped would be covered with several feet of fresh *débris*. The layers of gravel, not more than 3 to 6 inches thick, in which the gold is stored, rarely contain more than a grain of gold to the cubic yard.

28. There is one possible exception to this general condemnation. In the Brahmini river, near Durjing in Bonai, the alluvial flat would, if the gold content were sufficient, make an ideal "pond-dredging" proposition; but the tests made show a content of less than one grain to the cubic yard, which would be insufficient for profitable work.

29. To what extent this general conclusion is justified by the observations made, the expert will be able to judge on publication of the details; but it should be understood that the operations which have been conducted have not exhausted the *possibilities* of the area. Gold is undoubtedly widely distributed—indeed, almost universal—in the country examined, and future explorations *may* possibly reveal an instance of local concentration in payable quantities. But the results so far obtained, of a fairly conducted exploration, are sufficient to show that, in the absence of such definite evidence, gold-prospecting in this area could not, except in the possible instances named, be honestly recommended as a reasonable venture.

30. Whilst there are not wanting evidences of the persistent search for gold in Chota Nagpur during the past, there are no signs of extensive and deep ancient workings, such as are known in the auriferous tracts of South India. The general distribution of the metal evidently attracted numbers of native workers in the past, but there is no striking instance to show that their efforts were maintained for long in any

one place, and this interpretation of their results is in agreement with the conclusions of the survey just made.

5.—Iron and Manganese.

DHAR:
Mr. E. Vredenburg.
Mr. L. L. Fermor.

31. Amongst the questions of economic importance taken up during the survey of the Dhar forest, the rich iron-ores which form fault-breccias received some attention. They follow lines of faulting, the richest hematitic deposits being found along the great fault which Dr. W. T. Blanford long ago recognised as separating the Vindhyan and Bijawar systems throughout the entire district from east to west. The main, and at present insuperable, difficulty in connection with the development of these ores on a large scale is the absence of mineral fuel.

32. Manganese ores are widely distributed as a cementing material in the coarse conglomerate at the base of the Lameta series. These and some other minerals of possible value are now being analysed in the Laboratory, and will be reported in detail to the Dhar Durbar.

6.—Lead.

DARGOTI:
Dr. F. Noetling.

33. Dr. Noetling was deputed in April to the Dargoti State, north-east of Simla, to report on a lode of galena, regarded by the State officials as possibly valuable. His observations, supported by the assays made by the Curator, showed that the ore-body is neither rich enough nor large enough for successful exploitation.

7.—Petroleum.

BURMA:
Mr. R. D. Oldham.

34. During January Mr. Oldham examined the area covered by the newly delimitated blocks extending northwards from the ground described by the late Mr. G. E. Grimes [1] in the Pakoku district. The absence of topographical details on the maps prevented the preparation of a detailed geological map; but, by obtaining the positions of the boundary pillars, Mr. Oldham has succeeded in tracing the course of the anticline running northwards from the Yenangyat oil-field.

35. Throughout most of its course Prome beds are exposed in the axis of the anticline. The first oil-sand is exposed in the Ngapok-

[1] Mem. Geol. Surv. Ind., vol. XXVIII, pt. 1.

choung in block 48; the first four in block 57 and the first five in block 67, after which, on going north, the axis of the anticline pitches rapidly to the north, and the exposure of Prome beds dies out completely in block 123. The structure is that of a productive oil-field, and it is possible that a remunerative supply of oil could be obtained; but the free exposure of the upper oil-sands must have led to the escape of large quantities, and the absence of cover, owing to exposure of the Prome beds, will prevent the development of pressure which gives rise to the flowing wells of Yenangyat. At the same time, although the known oil-sands may be less productive than at Yenangyat, lower beds are made more accessible for exploration by the rise of the anticlinal axis, and the possibility of the occurrence of lower oil-sands may thus be tested by boring.

8.—Water.

BALUCHISTAN: *Mr. E. Vredenburg.*

36. During May Mr. Vredenburg was engaged in examining certain localities in the neighbourhood of Quetta to ascertain the possibility of obtaining a supply of artesian water, and points were selected where boring tests will be undertaken by the Local Government.

DHAR: *Mr. E. Vredenburg.*

37. During the survey of the Dhar forest attention was given to the question of water-supply, as the Nimanpur pargana is unfavourably situated in this respect. Nearly the whole of the pargana is in the condition of a terrace situated at an altitude intermediate between that of the deep Narbada valley to the south and the much loftier Malwa plateau to the north. The flatness of this terrace is remarkable, and is explained by its representing an ancient cretaceous pereplain of hard Bijawar and Vindhyan rocks, once more brought to light owing to the denudation of the easily-weathered, overlying Lameta rocks. From the foot of the Malwa scarp to the edge of the cliffs that overlook the Narbada, the level of this land remains almost everywhere the same, generally a little under 900 feet. Water-courses are scarce, and develope into gorges which gradually become deeper as they approach the Narbada. In many cases the stream-beds get lost in "swallow-holes," and the whole plateau is thus drained so effectively, that it is very difficult to obtain any water during the driest part of the year, notwithstanding the fairly abundant rainfall. This circumstance, together with the natural aridity of much of the Bijawar and Vindhyan outcrops, accounts for the region having never been occupied by a

strictly agricultural population, and since the abandonment of the iron mines, consequent on the importation of cheaper foreign metal, the district has been practically deserted. The physical conditions are the very opposite of those required for artesian wells. Nearly all the shallow wells fed by the surface water become dry during a part of the year, while the sinking of deep wells is too costly and too uncertain to be recommended. Hence in those parts of the plateau where patches of cultivable land exist (usually in connection with Lameta outliers), all efforts should be restricted to surface works, such as the construction of dams, and perhaps of small canals.

38. These remarks do not apply to the strip of land in the northern part of the pargana, along the foot of the Malwa scarp, where water usually exists at a small depth, and where the weathering of the basalt produces "black soil" of great richness.

B.—*GEOLOGICAL SURVEYS.*

1.—Assam.

KHASIA AND JAINTIA HILLS: *Mr. P. N. Bose.*

39. Mr. Bose continued his survey of the Khasia and Jaintia hills in Assam, extending the work on the one-inch scale over parts of Sheets 29, 30, 42, 43, and 44, and thus reducing by another 500 square miles the ground left unsurveyed.

40. The accepted relationships of the formations mentioned in the two previous General Reports (1900-1901, p. 20, and 1901-1902, p. 25) have not been modified by this work. But a small coal-bearing formation, near the head-waters of the Um Rileng, 11 miles north of Shillong, discovered since the submission of the last Report, and at first announced, on account of the peculiar character of its coal, as cretaceous, is now doubtfully given a post-tertiary age by Mr. Bose. He has found, on tracing the rocks further westward into the valley of the Kakri river, within a short distance of Laidom, where the cretaceous rocks are typically developed, that the lithological dissimilarity between the new beds and the cretaceous is so great that he now doubts his original correlation. On account of the imperfectly consolidated character of the Um Rileng beds, he is inclined to regard them as comparatively recent in age. But the form of evidence is admittedly weak, and as there are signs of considerable changes in the physical features of the area since the deposition of the Um Rileng beds, the age of the formation must remain, in the absence of fossils, undetermined. The attempts

made to test the value of the coal-seams have been reviewed on a previous page (p. 8).

2.—Baluchistan.

Mr. E. Vredenburg.

41. The long-controverted question as to the age of the Takatu mountain near Quetta has now been definitely settled. Some years ago Mr. F. H. Smith made a carefully detailed survey of the ranges, from which it became evident that the massive limestone, forming the main line of peaks, with a scarped face to the south-east and a dip-slope to the north-west, does not really overlie the cretaceous rocks of the lower ranges to the south-east, but has been brought into its place by an overthrust fault. The opinion as to its eocene age upheld for many years by previous observers could no longer, therefore, be maintained. Some fossils showing mesozoic affinities were also found, but not sufficiently characteristic for a more precise determination of the age. Following Mr. Smith's indications, Mr. Vredenburg came across several localities where the fossils are more plentiful, the most abundant of all belonging to two species of *Spiriferina*. These fossils occur in a thick series of shales and flaggy limestones, extensively developed in several parts of Baluchistan, and of an age which cannot be later than liassic. In normal sections they always underlie the great formation appropriately named by Mr. Oldham the "massive limestone," in whose uppermost strata callovian fossils have been described by Dr. Noetling.[1] It is the latter rock, and not the Nummulitic eocene limestone, that forms the most conspicuous portion of the Takatu.

3.—Burma.

EXPLOSION CRATERS, LOWER CHINDWIN DISTRICT: *Mr. R. D. Oldham.*

42. During the course of his work in the Lower Chindwin district, Mr. Oldham paid special attention to the peculiar, crater-like hollows occurring in the tertiary rocks. These hollows have precipitous sides, and are sometimes a mile or more in diameter, occasionally including small lakes of salt water; in one case near Laske, there were three confluent hollows, with low cross-ridges of volcanic ash between them, making a depression 1½ miles long, and reaching, in the centre and deepest hollow, 150 feet below the general surface of the country. The fragmentary materials in the country around include fragments of andesitic lava, mixed with blocks derived from the tertiary

[1] Pal. Ind., ser. XVI, vol. I, pt. 1.

beds; but unmistakable volcanic tuffs are found near by, lying on the pliocene sandstones, the original shapes of the accumulations having been modified by recent erosion. There are eleven of these curious pit-craters in the district, arranged along a line running about N.-E.—S.-W. for a distance of 13 miles, thus suggesting their connection with some tectonic fissure, which, however, has not been otherwise suspected or proved. They were evidently formed after the cessation of the normal volcanic activity known to have occurred in the area, and were produced, according to Mr. Oldham's judgment on the facts, by sudden and violent explosions of gases, not followed by ordinary volcanic ejecta, but beginning and ending abruptly. It is interesting to note that the volcanic material of the neighbourhood is andesitic in its character, as the most violent of explosive eruptions have been those connected with andesitic material, the recent eruptions in the West Indies having added further instances. The full paper will be published in the *Records*, which are to be revived.

NORTHERN SHAN STATES:
Mr. T. D. LaTouche.
Mr. P. N. Datta.
Mr. G. E. Pilgrim.

43. The work which has been done in the Northern Shan States by Messrs. LaTouche, Datta, and Pilgrim, requires either a detailed explanation on account of the difficulties which have arisen, or a brief mention on account of the few indisputable conclusions which have been obtained with regard to the stratigraphical characters of the country. The difficulties, treated at considerable length in the reports for 1899-1900 and 1900-1901, are not yet removed, and the conclusions, stated more precisely in 1901-1902, have yet to be substantiated by palæontological work. The collections of fossils made during the past four seasons have now been sent to England for critical examination, and until they are accurately determined, the questions of correlation of the systems in Upper Burma with those on the European standard scale must be kept in abeyance.

44. The premature discussion, however, of the question of correlation has regretfully obscured the actual observations, and has retarded the work of mapping the local natural groups of strata, which should be recognised and mapped as the first duty of the survey, apart from the interesting question of equivalence with the recognised systems of Europe. No system of strata in India is coeval, beginning and finish, with any one in Europe, and the use of European terms should follow, not guide, the work of outlining formations on our maps. Whether a system of strata is palæozoic or mesozoic the essential

characters which give it an individuality as a system should be delineated and mapped, and that work will represent so much positive progress whether its exact age can be determined or not.

45. In spite, however, of the confusion and the time which has been wasted over purely academic questions, the detailed lithological and stratigraphical description of the country has forced a recognition of certain of the groups with pronounced individuality, and the work which has been done in mapping, describing, and collecting from these represents solid and satisfactory progress. The formations about which there is no possible doubt have been outlined, and large collections of fossils have been made.

46. Mr. LaTouche has covered the new sheets, Nos. 239—241, published since the last report, and has completed the work partially done during the previous season on Sheets 285—287. He has also made a traverse through the Ruby Mines district, and, as far as the thick jungle would permit, has mapped the courses of several bands of the crystalline limestones in which the ruby is found. The details will be published when the survey has been completed; meanwhile, Mr LaTouche, who is now on furlough, has taken the opportunity of obtaining the opinions of specialists at home on the fossils which have been collected, and will endeavour to arrange for their description in Europe in the hope of being able to supplement the field observations with palæontological data sufficiently precise to permit of correlation.

47. Mr. Datta has similarly extended the survey work to the east and south, completing Sheets 332 and 333, and covering parts of 331, 379, and 380.

4.—Central India.

DHAR FOREST.
Mr. E. Vredenburg.
Mr. L. L. Fermor.

48. Mr. Vredenburg's services were lent for the field season to the Dhar Durbar, and, with the assistance of Mr. Fermor, he made a detailed survey of the Nimanpur pargana, generally known as the Dhar forest. The observations made on minerals of economic value are noticed separately (pp. 14 and 15), but in addition to these some questions of geological interest have been developed and settled. As an example of the three-fold work of the geological surveyor—the delineation of formations on the map, the application of newly-discovered phenomena to current geological problems, and the recognition of possible occurrences of material valuable from an economic stand-point—Mr. Vredenburg's work in this area merits the highest degree of commendation.

49. The most important amongst the questions which can fairly be regarded as now settled, is the age of the sandstones and conglomerates, formerly regarded by Mr. J. G. Medlicott and Dr. W. T. Blanford as part of the Lameta series of rocks which were deposited on the old Gondwana continent before it was overwhelmed by the great flows of Deccan trap in uppermost cretaceous times.

Later writers on the area came to the conclusion that some exposures of the sandstones regarded as Lameta probably belonged to the Gondwana system, and hopes were consequently entertained of finding coal in this area. The formation is fairly constant in consisting of an upper division, in which the prevailing sandstones are associated with shales and calcareous beds, resting on a lower division of conglomerate of well-rounded pebbles, embedded in clay or loose sand, or cemented by calcite, oxides of iron, or manganese Throughout the greater portion of the area examined during the season this formation is unfossiliferous; but at the south-western extremity of the map (fig. 2), near Barwaha in Holkar territory, the conglomerate contains typical Bágh (cretaceous) fossils. The fossiliferous conglomerate is lithologically identical with that which everywhere else in the area underlies the supposed Gondwana sandstone, and here also actually underlies the sandstone previously regarded as Gondwana. It is quite clear, therefore, that Dr. Blanford's original correlation of these beds with the Lametas was correct. His conclusions, based on lithological similarities, have now been confirmed by observed continuity of the sandstone and conglomerate without fossils to the sandstone and conglomerate with unmistakable cretaceous forms.

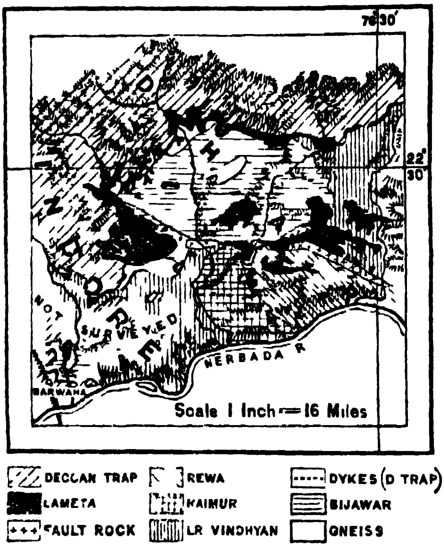

FIG 2.—*Geological map of the Dhar Forest.*

50. It follows also from these observations that the Lameta and the Bágh series are of the same age, the former being the deposits laid down in fresh water on the Gondwana continent, whilst the latter are those formed at the same time in the adjoining sea. The Barwaha exposure

thus indicates approximately the easternmost limit of trespass by the cretaceous (cenomanian) sea.

51. In another way this work has been interesting as a contribution to the physical geography of the old land area which was overwhelmed by the great Deccan lava-flows in uppermost cretaceous times. In places where atmospheric agents have cut through the protecting envelope of trap, the old weathered surfaces of the Lameta series have been exposed, showing ferruginous and manganiferous laterites, like those of modern times, and revealing the old irregularities of surface due to river action in cretaceous times. The filling-up by the lava-flows of the old ravines cut in the Lameta sandstones has led some previous observers to false conclusions with regard to the relative ages of some exposures of Lameta sandstone and adjoining trap. Near Chandgarh, for instance, where the Narbada cuts through a thick conglomeratic bed, the latter, on account of its high level, was formerly taken to be a sub-recent accumulation in the river valley; but Mr. Fermor, who crossed the exposure early in the season, was struck by the absence of basalt and agate pebbles amongst the boulders, as one would expect in a conglomerate formed at the expense of the Deccan trap. On returning later on, in accordance with Mr. Vredenburg's instructions, to examine the exposure more critically, it was found that the apparent higher position of the conglomerate was due to the Deccan trap having filled-in a deep valley in the Lameta beds.[1]

52. Observations which give us glimpses of the old cretaceous landscape which was obliterated by the great lava-flows do more than satisfy geological curiosity. The Deccan trap has protected the mineral wealth of the continent for over 200,000 square miles, and it probably hides more coal than that which has escaped the uninterrupted ravages of the weather in the parts of the country exposed throughout the subsequent tertiary era. The valuable seams of coal, for instance, accidentally exposed by the notch cut out of the trap in the Pench valley in the Central Provinces gives an indication of what is still hidden below.

[1] The recognition of a cretaceous age for these beds formerly regarded as sub-recent, leads us to suspect that the same may be true of similar deposits in other parts of India, for instance, those in which are situated the so-called alluvial diamond-workings of Bundelkhand. There are many features in connection with these deposits which confirm the suspicion that they are not recent alluvial deposits, but are probably lately uncovered patches of the Lameta series, and this conclusion, if established, will have an important bearing on prospecting operations in Central India.

5.—Kashmir.

53. Dr. Noetling was deputed to Kashmir in May to enquire into the relations of the permo-triassic rocks to those which, in the Salt Range and in the Central Himalayas of Spiti and Kumaon, have proved to be of such great interest to palæontologists. Amongst the results of Dr. Noetling's work, the discovery of the fossil ferns, *Gangamopteris* and *Glossopteris*, in beds apparently below permian marine strata has an important bearing on the geological age of the Lower Gondwana beds in Peninsular India—a question on which the Geological Survey of India had for many years to stand alone, and without the support of its own palæontologist. Whilst the upper limit of the Gondwana system in Peninsular India could be defined with precision as upper jurassic, on account of the trespass of the sea and the deposition of characteristic marine fossils in beds containing Upper Gondwana forms, there remained the great thickness of beds below in the Peninsula with fossil plants, amongst which *Glossopteris* and *Gangamopteris*, occurring in the lowest stages, indicated (according to the European key to the palæontological cipher) a jurassic age also. Relying on the accuracy of their stratigraphical work, the Geological Survey, led in this question by Dr. W. T. Blanford, insisted on the greater age of the Lower Gondwana rocks, and on purely indirect evidence fixed the base of the great system, in spite of the testimony of the *Glossopteris* flora, as approximately equivalent to the permian of Europe. Turning around to question the validity of the doctrines by which the Lower Gondwanas were considered to be jurassic on account of their fossil plants, the Geological Survey added to the strength of Professor Huxley's contention that evolution amongst the inhabitants of isolated land-areas proceeds at dissimilar rates, in contrast to the greater uniformity in the distribution of marine forms; and that, instead of the Lower Gondwanas being jurassic in age, the evidence pointed to the existence in India (and in Australia, Africa, and South America, where similar rocks occurred) of *Glossopteris* and its relatives several geological ages before these forms made their appearance in Europe and in northern lands generally.

Dr. F. Noetling.

54. The position taken up finally became strong enough—strengthened, in fact, by much, and often bitter, controversy—to force conviction on the geologists at home; but still direct and positive

proof remained wanting. Now, however, if Dr. Noetling has correctly read the facts recorded in Kashmir, the final point has been established by direct evidence. The discovery is sufficiently important to merit an immediate record of the essential details.

55. At Khunmu, in the Vihi valley, 15 miles south-east of Srinagar, a series of volcanic beds are covered in order by beds of quartzitic sandstones and unfossiliferous limestones, on which shales containing remains of *Gangamopteris* were found, followed conformably by chert beds, and a calcareous shale with further remains of *Gangamopteris*, associated with a ganoid fish of permian affinities, and fragments of a skull of *Archegosaurus*. There is then a break in the observations, due to the slopes being covered by talus deposits, and the next beds exposed, dipping in the same direction, and presumably following the plant-bearing bed without a break, contain *Fenestella* with other *Bryozoa*. The *Fenestella* beds are covered by limestones with *Spirifer derbyi*, *Productus indicus*, and other well-known Salt Range fossils, which conclusively prove the permian age of the beds.

56. Accepting Dr. Noetling's opinion that the gap in the exposures could not possibly hide a fault (which might have brought the permian limestones into their apparent position above the plant-bearing beds) the section he has described shows by direct evidence from marine fossils, that the *Glossopteris* flora did actually exist in India in permian times. At this distance from the late seventies, when the position of the Geological Survey was so strongly assailed, the discovery produces no further comment than the remark that the plants are just where they ought to be expected. But those who took part in the controversy, and know of the difficulties of trusting to the defence of indirect evidence, will, as many as are still living, receive the announcement of this simple fact with satisfaction. To them, and especially to Dr. Blanford, who has left such a monument of solid work in India, my congratulations are offered in the name of my predecessor, under whom the work was done, and in the name of my colleagues.

6.—Madras.

VIZAGAPATAM HILL TRACTS: *Mr. C. S. Middlemiss.*

57. The area examined embraces the lower plainward edge and fringe of the 3,000-feet plateau lying to the north and south of the Salur-Jeypore ghát road, and included in Sheet 108 of the Atlas of India (1 inch = 4 miles), as well as the greater part of Sheet 93 S.-E., left over

from last year. To the above may be added a route traverse across Sheet 93 N.-F., *viâ* Jeypore, and also a flying visit to the manganese mines of Kodur (Garavidi, on the Bengal Nagpur Railway).

58. The season's work has again resulted in the discovery of nothing but crystalline rocks and the unfossiliferous old strata of probably Cuddapah age. The main groups of the crystalline rocks in the Vizagapatam hill tracts have now been outlined, and except for two small patches, one in the north-east of Vizagapatam district and the other in the south-west on the borders of Godavari district, this blank formerly existing in the geological map of India has been filled in.

59. The rock-groups fall naturally into four main bands, which, with their N.-E.—S.-W. trend, determine the physical contours of the country. The north-western band, lying parallel to and adjoining the Bastar State, is a complex of hornblendic and micaceous gneisses and schists, often containing potstone, quartzites, frequently ferruginous, bands of augen-gneiss, forming the hills, charnockite in small quantity, and younger diabase-dykes. The country composed of these rocks is, generally speaking, a flat plateau, or set of two or more plateaux ascending by steps from 800 feet in the south-west end to over 1,000 feet in the north-east near Jeypore. This plateau bears a thick layer of soil of a bright red colour, through which the unaltered rocks occasionally protrude as isolated hills and on the edges of the ghâts.

60. With a fairly well-marked scarp and rise of about 1,000 feet, the boundary of the next band of rocks is marked off sharply from the first. This band is composed mainly of the charnockite series with associated khondalites, and grades into the third band on its south-east side, where, in addition to the charnockites and khondalites, gneissose granite and granulites make their appearance. These two—the second and third band—together form a rough, hilly country, traversed by flat, open valleys. The khondalites are regarded as originally sedimentary rocks, now completely metamorphosed by the intrusions of charnockite and granite. Amongst the results of contact-action Mr. Middlemiss has cited bands of magnetite, limonite, and manganese ores near the junction of the khondalite series and the igneous masses.

61. The south-eastern edge of the third band forms a well-marked scarp traversed in the usual way by ghâts, as the rapid drop occurs from the 3,000-feet plateau on to the plains to the east. In this low land, forming the fourth band, the rocks are mainly of the khondalite series, through which occasional bosses of gneissose granite and charnockite protrude.

62. The large mass of crystalline rocks thus briefly described contains the usual great variety of lithological types, a few of which, on account of their exceptional characters, deserve special notice. Near Koraput, for instance, Mr. Middlemiss found a band of elæolite-syenite gneiss, which is now the second instance of this interesting rock-group in Peninsular India, the first found being that of Sivamalai in the Coimbatore district.[1]

Another rock-band contains so many exceptional minerals that the specimens will require a detailed study for their identification. Sapphirine, a prominent constituent of one of these bands, is a mineral which has only been found in one other locality, namely, Fiskernäs, in Greenland. This band has been traced for some 30 miles from Guda to Sampangputi, and the study of the large collection of strange types obtained will certainly lead to results of considerable mineralogical interest.

63. Mr. Middlemiss is of opinion that the high-level laterite of these hills is a definite sedimentary deposit laid down in water. It is limited, he reports, to a fairly constant level, surrounding the hills like a shore-belt, through which the bare rocks now rise to superior heights, and were, he thinks, "islands in the lateritic age." On the inward side of the terraces there is, in each case, a shingle deposit of rolled and partly rounded pebbles of the underlying khondalite rock, set in a pisolitic laterite matrix. But no fossils of any sort have been found. This is an addition to the many theories which have been advanced to account for this peculiar formation, and it can only be discussed with fairness after a full display of the data. Judging, however, by the summary of observations at my disposal, I should not be disposed to regard this new suggestion as one likely to affect the growing conviction that laterite is due to a form of rock-decomposition peculiar to, or at any rate specially prominent in, moist, tropical climates.

7.—Punjab.

SALT RANGE: *Dr. F. Noetling. Prof. E. Koken.*

64. In accordance with instructions from the Right Honourable the Secretary of State, Dr. Noetling was deputed, during the cold weather of 1902-03, to accompany Professor E. Koken of Tübingen on his tour through the Salt Range. Only short notes of the observations made have been submitted by Dr. Noetling, and in these two important conclusions requiring further detailed support have been reported.

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[1] Memoirs, Geol. Surv. Ind., vol. XXX, pt. 3.

65. The peculiar salt-marl, lying below the cambrian strata, has been a puzzle to every worker in the Salt Range: the preservation of large masses of salt since pre-cambrian times, as its stratigraphical position appeared to indicate, is without a parallel; and the fact that other salt deposits not far off appeared to be of tertiary age, as well as the abnormal characters of the salt-marl itself, have combined to suggest that its position immediately below lower cambrian beds must have been attained by some process other than normal sedimentation. These points have been noticed by many previous workers, who felt unable to offer a satisfactory explanation of the apparently anomalous phenomena. Dr. Noetling reports now that there are evidences of the whole sedimentary series, from cambrian to tertiary, having been thrust bodily in a southerly direction over the salt-marl, and that the latter is probably but another exposure of the tertiary salt-bearing formation like that represented at Kohat. The idea thus involves an extension of the thrust-plane noticed by Mr. A. B. Wynne many years ago near Kalabagh. There are many questions to answer before accepting this plausible explanation of the difficulty, and it is a subject of sufficient importance to merit more detailed observations than have been reported.

66. The other point of interest is the discovery of further, and apparently conclusive, evidence in support of the theory held by the Department that the Salt Range boulder-bed is due to glacial action in permian times. On the northern slope of the western branch of the Makrach glen, where the boulder-bed has been removed by the weather, typical glacial striæ were found on the cambrian magnesian sandstone, over which the ice must have moved. Evidence was obtained also to show that the facetted boulders, which have been so puzzling to glacialists, must have been planed in their peculiar way by being embedded in the rocks over which the glacier and its ground-moraine moved, a new face being cut when the boulder became shifted and turned over. It is to be regretted that specimens and drawings in illustration of these interesting observations have not been offered to the Department, the only account of the details available being those published in a series of joint papers by Drs. Koken and Noetling in the *Centralblatt für Mineralogie, Geologie und Palæontologie, 1903.*

T. H. HOLLAND, *Director,*
Geological Survey of India.

CALCUTTA;
August 1st, 1903.